Policy Options to **Decarbonize** Ocean-Going Vessels

GOLDMAN SCHOOL OF PUBLIC POLICY
UNIVERSITY OF CALIFORNIA BERKELEY

Commissioned by
PACIFIC ENVIRONMENT

Policy Options to **Decarbonize** Ocean-Going Vessels[1]

May 21, 2024

Prepared For:

PACIFIC ENVIRONMENT

Jamie Yates, *Climate & Renewable Energy Analyst*
Teresa Bui, *Climate Policy Director*

Pacific Environment
E: jyates@pacificenvironment.org

Prepared By:

GOLDMAN SCHOOL OF PUBLIC POLICY
UNIVERSITY OF CALIFORNIA BERKELEY

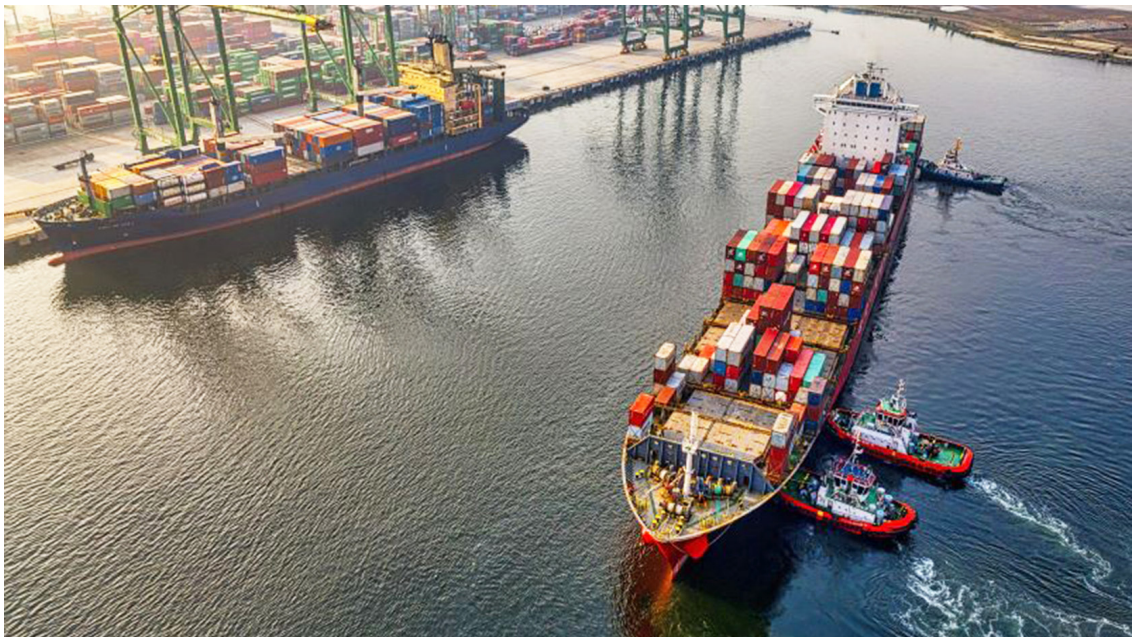
David Wooley, *Director*
Elizabeth Larsen, *Graduate Student Researcher*
Michihiro Horakawa, *Graduate Student Researcher*

Center for Environmental Public Policy
Goldman School, University of California, Berkeley
https://gspp.berkeley.edu/research-and-impact/centers/cepp
davidwooley@berkeley.edu

[1] This report, and the accompanying Technical Assessment are available at the UC Berkeley, Goldman School of Public Policy, Environment Center website: https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/ocean-going-vessel-de-carbonization

To request this document in an alternative format, including large print, braille or electronic formats, please contact David Wooley at davidwooley@berkeley.edu.

Table of Contents



Maersk's green bio-methanol vessel *Laura Mærsk* in operation October 2023. Maersk has been a first-mover towards maritime decarbonization, but Maersk and all carriers must continue to strive for truly zero emission fuels.

Photo: Courtesy of Jens Dohrn/Open Verse

Section 1: **Introduction**

Ocean-going vessels (OGV) are a significant source of air pollution and greenhouse gas emissions (GHG).[2] This impact is projected to grow over the next few decades.[3] It will be very difficult to meet national and global climate targets without reductions in large vessel emissions. Nitrogen oxides (NOx), particulate matter (PM), sulfur oxides (SOx), and other "conventional" air pollutants are co-emitted with GHG emissions from ships. Deep reductions in these emissions are needed to meet national air quality standards and protect health in port and coastal communities.

Until recently even progressive governments had not prioritized GHG emission reductions from shipping. This was in part due to immature zero-carbon ship propulsion systems and fuels. Policy changes faced opposition from the maritime industry, and policymakers were focused on the initial ramp-up of lower-cost decarbonization options (e.g. electric vehicles and renewable energy). All this has changed significantly in the past 5 years.

---

[2] See, *Final, Maritime Clean air Strategy*, Port of San Diego, October 2021 page IV.2, https://pantheonstorage.blob.core.windows.net/environment/20211214-Final-MCAS.pdf; Ramboll, *Port of Oakland 2020 Seaport Air Emissions Inventory Final Report*, November 2021, https://www.portofoakland.com/files/PDF/Port%20Oakland%202020%20Emissions%20Inventory%20Final%20Report.pdf (Table ES-1b shows GHG emission from ocean going vessels (92,379 tons CO2e in 2020) are responsible for about 57% of all GHG sources in the Seaport.); California Air Resources Board, *2021 California Ocean-Going Vessels Emissions Inventory,* March 2022, pages 4 and 30, "Specifically, the vessels' diesel engines and boilers continue to be one of the largest contributors of criteria pollutants in the state, including oxides of nitrogen (NOx) and particulate matter (PM). OGV are one of the few categories that are expected to continue to increase emissions contributions even as other sources are reduced by strict engine standards and in-use requirements... https://ww2.arb.ca.gov/sites/default/files/2022-03/CARB_2021_OGV_Documentation.pdf

[3] Without further action, the global GHG emissions would grow 50% by 2050. www.frontiersin.org/articles/10.3389/fmars.2022.1076352/full. *The paper cites the IMO's Fourth Greenhouse Gas Study, 2020.* Available at *https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx*

Today there is strong momentum toward zero-carbon shipping among national, regional, and local governments, international organizations, vessel owners, cargo shippers, port authorities, and fuel producers. Part of the attention to shipping emissions stems from synergies with efforts to decarbonize other sectors of the world economy. Heavy-duty road transport and heavy industry facilities (refining, steel, chemical and cement, and wastewater management) are often concentrated near maritime ports and can share decarbonization infrastructure (e.g. renewable hydrogen and zero-carbon liquid fuel production, and high-voltage electric grids).

In early-2023, the Goldman School began research to assess policy options to decarbonize ocean-going vessel operations, complementing our earlier work on emissions from port operations. We started with a survey of policy developments affecting GHG and air pollution emissions from OGVs. The accompanying spreadsheet lists major policy developments in recent years and forms the basis for this narrative.[4]

Recent highlights from that compilation include:

- An agreement in July 2023 by the International Maritime Organization (IMO) on GHG reduction targets and plans to develop implementation measures to achieve deep reductions from OGV operations beginning this decade. See discussion below.[5]
- A joint declaration from CEOs of leading global shipping lines at COP 28 (December 2023) called for an end to the construction of new fossil-only powered ships. [6] The statement includes a call for national and subnational action to reduce emissions from OGVs.
- Action in the European Union to include vessel emissions in the EU Cap and trade system and creation of a carbon intensity fuel standard for ships calling at EU ports.

---

[4] Wooley, et al *Condensed Catalog of Policy & Regulation Initiatives to Reduce Ocean Going Vessel Emissions*, available at https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/ocean-going-vessel-decarbonization

[5] A New York Times article, reporting on IMO follow up meetings in March 2024, describes first steps toward strategies to implement the 2023 GHG Strategy "The United Nations agency, which regulates the shipping industry, is essentially committed to creating the world's first global carbon price... The proposal would require shipping companies to pay a fee for every ton of carbon they emit by burning fuel. Shipping accounts for roughly 3 percent of global greenhouse gas emissions, slightly more than aviation. Taxing its carbon emissions would very likely raise tens of billions of dollars a year for climate policy." - *A First Step Toward a Global Price on Carbon* (Andreoni, Bearak) https://www.nytimes.com/2024/03/28/climate/a-first-step-toward-a-global-price-on-carbon.html

[6] The companies' joint declaration also called for an efficient pricing mechanism to make green fuel competitive by distributing the premium for green fuels across all fossil fuels used in shipping. Signatories include: CMA CGM Group, A.P. Moller – Maersk, Hapag-Lloyd, MSC Mediterranean Shipping company, Wallenius Wilhelmsen. https://climatechampions.unfccc.int/wp-content/uploads/2023/12/COP28-Green-H2-Joint-Statement.pdf; https://www.maersk.com/news/articles/2023/12/01/shipping-ceos-join-forces-to-accelerate-the-decarbonization-of-the-global-maritime-transport; https://www.marinelink.com/news/shipping-ceos-call-end-fossilonly-509890?utm_source=MR-ENews-Weekdays-2023-12-05&utm_medium=email&utm_campaign=MR-ENews;

These actions represent a major step-change in the ambition to phase out fossil fuels in the maritime sector. For example, to achieve the targets set out in the IMO 2023 Strategy, the average ship's GHG intensity will need to be reduced by 86% by 2040. Achieving this will require a combination of strategies including efficiency measures, hybrid propulsion systems (including wind assist, battery-electric motor), operational changes, and rapid growth in the use of zero-emission fuels, notably those derived from waste-biomass and green hydrogen-derived fuels. Positioning the global shipping sector to achieve deep GHG emission reductions will require the application of these measures starting now. For example, some estimates would require a relatively modest green hydrogen production volume of 5 million tonnes by 2030, (equates to around 29.8 Mt of ammonia or 28.1 Mt of methanol), but growing rapidly to up to 90 million tonnes by 2040."[7]

Notable developments in clean energy supply chains for OGVs include the following:

- In 2022 and 2023 there was massive private sector investment in zero-carbon fuel production and fueling infrastructure.[8] In the U.S., billions of dollars are being invested to reduce emissions from ports and to develop green hydrogen supply chains.[9]
- Agreements by governments and maritime ports on both sides of the Pacific and Atlantic oceans to implement transoceanic, zero-carbon trade corridors.[10]
- Hundreds of new ocean-going vessels are under construction to use zero-carbon propulsion systems.[11] Many existing ships are being modified to reduce emissions through conversion to low-carbon liquid fuels, efficiency measures, and wind energy.[12]
- Agreements to bunker green methanol have been announced for the Ports of

---

7 *Climate Action In Shipping*, *Progress towards Shipping's 2030 Breakthrough*, https://climatechampions.unfccc.int/wp-content/uploads/2023/11/GTZ_ClimateActionInShipping2023-17112023.pdf. A statement that addressed the need for rapid buildup of a green hydrogen supply chain for zero carbon shipping fuel, was released by a consortium of ship owners, cargo owners, maritime ports, equipment manufacturers, fuel suppliers and NGOs. *COP28 Green H2 Joint Statement,* https://climatechampions.unfccc.int/wp-content/uploads/2023/12/COP28-Green-H2-Joint-Statement.pdf

8 For example, Maersk made a $1 Billion order for e-methanol ready vessels to be produced by Hyundai Heavy Industries by 2025. Additionally, the Port of Hamburg participates in international research projects such as the development of a seagoing vessel with a methanol fuel cell propulsion system (HyMethShip). https://www.bloomberg.com/news/articles/2022-10-05/maersk-expands-green-fleet-with-new-order-for-six-large-vessels?cmpid=BBD013023_TRADE&utm_medium=email&utm_source=newsletter&utm_term=230130&utm_campaign=trade#xj4y7vzkg; https://www.hamburg-port-authority.de/fileadmin/user_upload/Geschaeftsbericht/Sustainability_Report_2020.pdf

9 US Department of Energy, *Regional Clean Hydrogen Hubs* https://www.energy.gov/oced/regional-clean-hydrogen-hubs-0; U.S.Environmental Protection Agency Clean Ports Program, https://www.bing.com/search?q=us%20epa%20clean%20ports%20program&FORM=ARPSEC&PC=ARPL&PTAG=32165; The White House, *Fact Sheet: Biden-Harris Administration Announces Key Infrastructure Funding to Electrify Ports,* (describing $3.6Billion in USDOT, USEPA grant programs) https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/05/fact-sheet-biden-harris-administration-announces-key-infrastructure-funding-to-electrify-ports/#:~:text=Thanks%20to%20the%20President%E2%80%99s%20Bipartisan%20Infrastructure%20Law%2C%20MARAD,eliminating%20local%20pollution%20and%20cutting%20greenhouse%20gas%20emissions.

10 See, Global Marine Forum, *Annual Progress Report On Green Shipping Corridors* 2023, https://cms.globalmaritimeforum.org/wp-content/uploads/2023/11/Global-Maritime-Forum_Annual-Progress-Report-on-Green-Shipping-Corridors_2023.pdf;

11 *Ørsted opens a new era in green shipping by breaking ground on Europe s largest e-methanol project,* May 24 2023 https://www.ajot.com/news/rsted-opens-a-new-era-in-green-shipping-by-breaking-ground-on-europes-largest-e-methanol-project

12 See footnote 21, infra.

Shanghai (2026-2027), Antwerp-Bruges, Savannah, and other major ports.[13] Biofuel bunkering sales at the Port of Singapore tripled between 2022 and 2023 to 520,000 tonnes in 2023).[14]

- Thirty-five major retail brands including Amazon, IKEA, Phillips, Levi Strauss, Schneider Electric, Meta, Nestle, Electrolux, and REI Co-op have joined the coZEV Initiative. Signatories to the initiative aim to only purchase ocean freight services powered by zero-carbon fuels by 2040.[15] In September 2023, coZEV launched an RFP for 600,000 TEUs over the next three years powered by zero-emission fuels.[16]

While there has been remarkable progress on shipping decarbonization, much more is needed. The IMO still needs to take meaningful, and enforceable action to implement its 2023 targets. Complementary action by ports, national and subnational governments, and industry leaders is important to set the context for and drive momentum to achieve IMO targets. Governments, at all levels, also need to take action to support and condition their industrial sectors to new technologies, global fuel commodities, fuel production and bunkering infrastructure and changing capital and cargo-transport markets. Subnational governments need to prepare local and regional economies for changing fuel production, ship design, port operations, and workforces. Subnational policy leadership can send powerful signals to national and international policymakers.

Action on these policy fronts must be complemented by ambitious changes in other sectors. For example, decarbonization of electric power generation will be key to the production of low or zero-carbon vessel fuels.[17] It will also be important to rapidly scale up production of green hydrogen in a safe and cost-effective manner.[18]

The policy landscape regarding emissions from OGVs is complex and dynamic. This paper seeks to inform policymakers, industry leaders, and stakeholders on the state of play for the decarbonization of OGV operations and identify leading policy options for national and subnational levels of government and private sector leaders.

The term "policy" in this paper is not limited to governmental action. We define the term to include corporate, trade association, port, and NGO decision-making and the

---

[13] https://www.portstrategy.com/environment-and-sustainability/shanghai-and-evergreen-team-up-on-methanol/1490515.article; https://www.portstrategy.com/environment-and-sustainability/methanol-bunkering-first-at-antwerp-bruges/1492496.article

[14] https://docs.google.com/document/d/1qk6TYXKXFJTgrisXiAJC-GCoGicuchztMuwLa5vnSb0/edit

[15] https://www.cozev.org/img/110922_Roadmap%20to%202040.pdf; https://www.cozev.org/aboutcozev

[16] https://www.cozev.org/thelatest/amazon-electrolux-philips-and-over-20-other-major-global-companies-launch-historic-tender-to-accelerate-deployment-of-zero-emission-shipping

[17] See, ICCT, *Feasibility Study Of Future Energy Options For Great Lakes Shipping.* pp ii-iii, March 2024, https://theicct.org/wp-content/uploads/2024/02/ID-98-%E2%80%93-MARAD-report_final.pdf

[18] We use the term "green methanol" as a general category that includes e-methanol and bio-methanol. Bio-methanol is considered methanol that comes from waste streams, while e-methanol comes from green hydrogen and captured CO2. See, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/petrochemicals/021523-renewable-methanol-drives-maritime-industry-decarbonization-institute-ceo#:~:text=Bio%2Dmethanol%20is%20considered%20methanol,as%20renewable%20or%20green%20methanol.

development of voluntary markets. Actions by these entities have profound effects on international, national, and subnational policy. Collaborative efforts by shipping market participants can conceptualize, test, rationalize, and pilot practices and industry norms that influence government policy.

Our research supports strong optimism that this complex industry can change in ways to achieve a sharp reduction in global GHG pollution, retain prosperity, and protect national, subnational, and local interests.

Major Implications and Trends

Technology Shifts

In the past, regulatory measures to control emissions from OGVs have focused on control of conventional ship engine emissions, via gradually tighter engine emission controls, sulfur in fuel limits, efficiency improvements, shore power, and speed controls. While continuing to reduce conventional emissions, government and corporate policy today is moving toward: 1) in the short term, partial reduction of GHG emissions via drop-in low-carbon fuels and changes in operations (speed controls, efficiency measures, and hybrid propulsion); and 2) in the longer term, a phase-out of internal combustion engines that use fossil fuels.

The dominant short-term vessel GHG reduction strategy (low-carbon drop-in fuels) could achieve significant reductions in GHG, SOx, and particulate matter emissions, but is unlikely or uncertain to reduce NOx emissions. Since NOx emissions are a significant concern for areas experiencing unhealthy levels of ground-level ozone, any national or state cap-and-trade or in-transit strategy that relies on zero-carbon drop-in fuels will also need to require modern NOx control systems (e.g. proposals to require Tier III and Tier IV engine systems using Selective Catalytic Reduction (SCR) and flue gas recirculation).

At this time, it is too early to identify a dominant long-term strategy to eliminate GHG emissions in OGVs, but any strategy is likely to involve a range of technologies customized to vessel types, duty cycles, and access to low-carbon fuels. Some options include a move away from internal combustion engines (e.g. fuel cells, batteries, and wind, possibly in hybrid combinations) which could eliminate the need for NOx control systems. For long-term options that rely on internal combustion engines (e.g. 100% green methanol or biofuels), NOx emission controls will be needed.

Policymakers need to achieve a thoughtful accommodation of the two objectives, in order to: 1) continue progress to reduce exposure to conventional air pollution; and, 2) at the same time, redirect investment of government resources and private sector investment to zero-emission technologies and fuels. For example, research and demonstration of

efficiency and noise reduction measures for new and existing ships need to continue even as governments and industry look toward a complete transition to zero-carbon fuels and operations. However, investment in Tier III and IV engines, small efficiency improvements in fossil fuel combustion systems, and upgrades to port fossil fuel infrastructure could conflict with the need for research and capital investment in zero-carbon technology and infrastructure. Further research on this topic is needed.

Costs & Supply Chains

Green methanol appears to be a leading candidate for near-term GHG reductions in large OGVs. According to Lloyds Register, more than 143 methanol-ready ships were ordered in 2023 from prominent OGV owners and operators and 100 ships are being retrofitted.[19] The big questions about this shift include:

- Can the cost of green methanol be reduced; and,
- Is there enough green methanol feedstocks and production capacity to achieve deep emission reduction.

These concerns are lessened by recent procurement contracts for methanol supply and promising research on the use of green methanol in fuel cells for new ships.[20] But good faith efforts to transition to zero-carbon liquid fuels might be constrained by shortages of green methanol feedstocks.[21] Hence green methanol is likely to be used in combination with other zero-carbon technologies and operations to initially reduce and eventually achieve a full transition of OGV fleets.[22] Policy and voluntary market structures should recognize the need for multiple solutions and provide compliance flexibility (e.g. base compliance on lowered carbon intensity rather than the use of particular technology). Moreover, investment needs to anticipate the next stages of technical innovation, which might include the adoption of fuel cell and reformer technology for large ships.[23]

---

[19] Lloyds Register, *Shipping is sizing up energy transition opportunities*, January 11, 2024. https://www.lr.org/en/knowledge/insights-articles/shipping-is-sizing-up-energy-transition-opportunities/; Lloyds Register, *Engine Retrofit Report 2023: Applying alternative fuels to existing ships* https://www.ama-andros.gr/wp-content/uploads/2023/09/LR_101507_P4_Engine-Retrofit-Guide_2023.08.24_3.3_.pdf; *Hapag-Lloyd and Seaspan to retrofit five vessels to methanol propulsion* Apr 16, 2024,https://www.ajot.com/news/hapag-lloyd-and-seaspan-to-retrofit-five-vessels-to-methanol-propulsion

[20] The world already produces large amounts of fossil-based methanol, or grey methanol, mainly for use in petrochemical industries. Use of fossil-based methanol in shipping would not reduce GHG emissions relative to conventional oil-based bunkering fuels.

[21] The primary feedstocks for green-methanol are hydrogen, biomass, renewable electricity and captured carbon. These feedstocks also will be needed for other decarbonization strategies including aviation (Sustainable Aviation Fuel or SAF), steel and cement manufacturing. See, U.S. Department of Agriculture, *National Clean Hydrogen Strategy and Roadmap*, https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf?Status=Master

[22] Near term options include co-firing of green-methanol with other fuels; battery electric hybrid propulsion that optimizes green-methanol fuel use, and potentially provides the primary energy source for, near-shore operations, and short and medium distance trade routes. On potential for batteries in OGV, see, See, Jessica Kersey, Natalie D. Popovich and Amol A. Phadke, *Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping,* Nature Energy | VOL 7 | July 2022 | 664–674, www.nature.com/natureenergy.

[23] Combustion of green-methanol in ship engines has dramatic GHG benefits, but produces significant conventional air pollution emissions. Burning methanol derived from fossil fuel has virtually no benefits. Vessel owners and operators, and fuel suppliers must avoid the impression that actions to adopt methanol fuels are a 'deep fake" designed to prolong dependance on bunker fuel cofired with fossil-derived methanol or with only minimal amounts of green-methanol.

Fuels, Ships, and Ports

Policy approaches must simultaneously address vessels, fuels, and port infrastructure.[24] Zero-carbon port infrastructure and zero-carbon fuel manufacturing will be critical to the transition and can't be addressed as an afterthought. For example, if batteries emerge as an option for ships, ports and supporting electric grids will often need significant electric power supply system investment to meet ship battery charging demand. Ports may need to add low- and zero-carbon liquid or cryogenic fuel bunkering infrastructure. Zero-carbon fuel production near ports will be important to avoid supply chain constraints and to lower costs of fuel and compliance options.

The diversity of OGV types in California suggests that many different technology and policy solutions are needed to address different types of fuel and vessel configurations.

- Example: batteries may work for intercoastal and short oceanic voyages, and hybrid propulsion may work for some larger and smaller vessels.

2016 California Port Calls by Vessel Type

Vessel Type	Percentage of Total Calls
Container	44.3%
Tanker	21.0%
Ro-Ros/Auto Carriers	11.5%
Bulk Carriers	7.9%
Passenger Cruise Vessels	7.4%
Other	5.1%
General Cargo	2.8 %
TOTAL	100%

https://ww2.arb.ca.gov/sites/default/files/classic/msprog/tech/techreport/ogv_tech_report.pdf?_ga=2.176263653.1539937694.1701475865-233560686.1686860641

- We are in a period of rapidly evolving fuel and vessel technologies. Hence, interim steps are needed to achieve some immediate emission reductions that lead to other solutions to achieve full decarbonization.
- Policy solutions must simultaneously address fuels, ships, and port infrastructure.

[24] Recent experience in the offshore wind industry in the U.S. suggests that port infrastructure needed to support wind turbine and foundation assembly is, in some regions, underfunded. Ports are often publicly owned and need government support for large capital expenses.

Leadership

Initiatives to decarbonize OGVs should not be left solely to national and international governments. State, local, port, and private sector initiatives have been essential in building the current momentum toward marine transport decarbonization. These entities should not wait for leadership to emerge from the top, but must strategically push for action by national and international agencies while at the subnational level working to prepare infrastructure, markets, and demonstrations needed to accelerate and streamline the transition.

State leadership is especially important at this time. Ships traveling between U.S. and EU ports will soon be required to monitor and report on GHG emissions, gradually reduce the carbon intensity of fuel used, and purchase allowances for a portion of their GHG emissions (under the EU ETS). The main effect of this on U.S. shipping will be felt on ships traveling between East and Gulf Coast ports to EU ports (some ships travel between West Coast and EU ports but in smaller numbers, as the main trading corridor for West Coast port vessel calls is to Asia). If California (perhaps in concert with Oregon, Washington, and British Columbia) were to adopt complementary regulations to reduce emissions from ships arriving at its ports, it could effectively expand the reach of the EU regulations to the large number of vessels traveling between West Coast and Asian ports.[25] Similarly, complementary action by the U.S. government would multiply the impact of the EU regulations. In the near term, statements by California and US officials of intent to regulate OGV emissions would help ensure the adoption of effective implementation measures by the International Maritime Organization.

A Brief History of OGV Emission Control Policy

The current sea change in OGV emission control arises from a long slow burn of international, national, and state regulation of conventional air pollution emissions from ships. Conventional air pollution includes NOx, PM, SOx, and in certain cases volatile organic compound (VOC) emissions.

International agreements on the prevention of pollution from ships were first adopted in 1973. The International Convention for the Prevention of Pollution from Ships (MARPOL Convention) is administered by the United Nations' International Maritime Organization (IMO). The Convention first addressed air pollution when it was amended to add Annex

[25] Research by Transport & Environment shows that four out of every 10 ships globally visit a port in the European Economic Area. Looking at the ships that also visited China and the US, this number went up to over 8 out of 10 ships. *Opinion: New climate demands will spread far beyond Europe's borders* https://shippingwatch.com/regulation/article16792927.ece; citing, *Less is more: Regional shipping policy and global decarbonisation, Regulating shipping in Europe, the US and China could green 84% of the fleet,* November 2022, https://www.transportenvironment.org/wp-content/uploads/2022/11/COP27_world_country_MRV-3.pdf

VI, which came into force in 2005.[26] Annex VI set limits on SOx and NOx emissions from ship exhaust and prohibited deliberate emission of ozone-depleting substances. A chapter adopted in 2011 addressed mechanical and operational options to help reduce GHG emissions from ships.

Annex VI gradually improved efficiency, combustion efficiency, and a range of physical structures and operation parameters that affect emission rates for conventional and GHG pollutants. In 2010, the IMO issued regulations requiring all ships operating in emission control areas' (ECAs) to use low-sulfur fuel to reduce SOx emissions, as well as ships built after 2016 to be equipped with advanced "Tier 3" engines to reduce NOx emissions.[27] These requirements were adopted into the Environmental Protection Agency (U.S. EPA) regulations under the 1990 Clean Air Act amendments after the U.S. ratified Annex VI of MARPOL.[28]

These actions by the IMO were inspired by state government initiatives. The IMO's sulfur-in-fuel requirements followed action by the State of California to control particulate matter, SOx, and NOx emissions in coastal waters, leading to dual-fuel ship configurations to reduce emissions while ships operated within 24 miles of the CA coast.[29]

The California Air Resources Board (CARB) also adopted regulations to reduce both conventional air pollutants and GHG emissions from ships at berth. These focused on operations of ship in port, including:

- Two rounds of shore power regulations (2007 and 2020), called At Berth Regulation, require large vessels to plug into land-based electric systems and eliminate auxiliary engine emissions while in port.[30]
- Commercial harbor craft (CHC) regulations were adopted by CARB initially in 2008, with significant revisions in 2022.[31] The original regulations encouraged CHC owners to replace older engines with newer, cleaner ones. The 2022 revisions expanded the regulation to include more vessel types and require cleaner upgrades and newer technology, including the first in the nation zero emission mandate for ferries.[32]

---

[26] For a history of IMO and MARPOL see: https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/pages/Marpol.aspx-#:~:text=The%20International%20Convention%20for%20the,from%20operational%20or%20accidental%20causes.

[27] In 2020 IMO set a new more stringent limit on sulfur content of fuel oil. https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

[28] MARPOL was amended in 1978 in response to a spate of tanker accidents and entered into force in 1983. Annex I addresses pollution from oil, requiring double hulling. Annex II addresses pollution from transport of Noxious Liquid Substances. Annex III required a set of packing, marking, labeling, documentation and stowage requirements for harmful substances. Annexes IV and V address pollution by sewage and garbage discharges from ships.

[29] https://ww2.arb.ca.gov/our-work/programs/ocean-going-vessel-fuel-regulation

[30] https://ww2.arb.ca.gov/our-work/programs/ocean-going-vessels-berth-regulation

[31] https://ww2.arb.ca.gov/our-work/programs/commercial-harbor-craft

[32] https://ww2.arb.ca.gov/our-work/programs/commercial-harbor-craft

- California's emission inventory included GHG emission from ship operations within 100 miles of the coast.[33]

For the most part, however, federal and state governments in the US deferred to IMO on GHG emission controls and in some cases deliberately exempted OGVs from state and federal GHG emission controls. For example:

- Ship GHG emissions are not regulated under California's GHG cap-and-trade law (AB32).
- California exempts fuels used in ocean-going vessels from the state's Low Carbon Fuel Standard (LCFS), and does not allow clean maritime fuel producers to opt in as a credit generator.
- The federal government in 2023 authorized large amounts of infrastructure funding (Inflation Reduction Act and Infrastructure Investment and Jobs Act) and tax credits for GHG emission reduction. Some of these funds can be used to reduce GHG emissions from port operations and to support renewable hydrogen and biofuel production, storage, and fueling infrastructure, but funding is very limited for large vessel retrofits and construction, and production of low-carbon liquid fuels or ships (e.g. green methanol or ammonia).
- The U.S. EPA does not regulate GHG emissions from OGVs.
- The U.S. Renewable Fuels Standard (RFS) exempts fuels used in ocean-going vessels.[34]

California recently began to pay more attention to OGV GHG emissions.[35] A series of air quality planning documents (GHG Scoping Plan and State Implementation Plans), technical assessments, and workshop presentations reflect the state and port authority interest in addressing OGV GHG emissions.[36]

- As of 2021, CARB stated that cleaner marine fuels including hydrogen, methanol, and ammonia are emerging, along with alternative propulsion technology (batteries and fuel cells).[37]
- CARB is looking to explore measures to achieve additional reductions from in-transit, maneuvering, and at-anchor from ocean going vessels.[38] We recommend CARB consider: the use of low-carbon fuels in dual fuel operation capacity in

---

[33] https://ww2.arb.ca.gov/sites/default/files/2022-03/CARB_2021_OGV_Documentation.pdf. March 2022.

[34] Energy Policy Act of 2005, Pub. L. No. 109-56,119 Stat. 594; amended by the Energy Independence and Security Act of 2007. 42 U.S.C.A. §7545(o); Code of Federal Regulations, title 40, part 80, sections 1100 et. Seq.

[35] From 2009 through 2016, OGVs averaged 8,970 port calls annually in CA Ports.

[36] http://www.aqmd.gov/docs/defaultsource/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/ogv-presentationscombined-04-01-21.pdf.

[37] https://ww2.arb.ca.gov/sites/default/files/2021-10/2022_SSS_Draft_Measures.pdf (At the time of that report CARB's view was that, "There is no consensus within the maritime industry yet as to which alternative fuel(s) might be best suited for OGV applications.")

[38] Interim Evaluation Report | California Air Resources Board

ships (to accommodate "drop-in" zero-carbon fuels such as green methanol[39]); hybrid engine configurations (e.g. batteries in ships that use diesel turbine engines to reduce bunker fuel use near shore); emission trading options and other mechanisms to eliminate GHG emissions and criteria pollutants from ships by 2040.

- CARB staff plans to assess the feasibility, benefits, and cost-effectiveness of control technologies for bulk/general cargo vessels and vessels at anchor (which are not subject to emissions control requirements in the 2020 At Berth Regulation).
- CARB is also looking at incentive measures and research to encourage OGVs to voluntarily use cleaner engines/fuels, reduce emissions at anchor, or reduce speeds in coastal waters.[40]
- CARB plans to engage with the U.S. EPA and IMO to explore cleaner marine standards for OGVs and harbor craft and Vessel Speed Reduction (VSR) regulations for OGVs operating near U.S. ports.
- CARB participates in a Pacific Coast collaborative to reduce environmental impacts from shipping.[41]
- Local government and port authorities in California have begun to experiment with a range of grants and fees to incentivize cleaner ships. For example, the Port of Los Angeles offers reduced port fees for ships having cleaner conventional pollution emissions, based on the Environmental Ship Index (ESI). Several ports provide financial rewards for reduced speed near shore to both reduce engine emissions and avoid ship strikes of marine mammals. California Ports in recent years have begun to:
    - develop zero-emission trade corridor agreements with ports in other nations;
    - cooperate on measures to reduce conventional and GHG emissions from port and vessel operations; and,
    - to share information on low-carbon fuels and supporting infrastructure.

Nevertheless, until at least mid-2021, the main focus of industry and government attention has been to reduce NOx and particulate emissions from OGVs via cleaner conventional bunker-fueled engines and to attain national ambient air quality standards (for ozone and particulate matter).[42] State agency discussion of GHG emission reduction

---

[39] "Bio-methanol is methanol that comes from waste streams, while green-methanol comes from green hydrogen and captured CO2. Both classify as renewable or green methanol." https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/petrochemicals/021523-renewablgreen-methanol-drives-maritime-industry-decarbonization-institute-ceo#:~:text=Bio%2Dmethanol%20is%20considered%20methanol,as%20renewable%20or%20green%20methanol.

[40] California Air Resources Board, *Potential Future Measures for Reducing Emissions from OGVs*. 2022 AQMP Mobile Source Working Group. April 1, 2021.

[41] West Coast Governors Newsom, Inslee, Brown and B.C. Premier Horgan's Climate Partnership Sets Sights on Port Electrification and Maritime Decarbonization, https://www.pacificenvironment.org/press-releases/west-coast-governors-newsom-inslee-brown-and-b-c-premier-horgans-climate-partnership-sets-sights-on-port-electrification-and-maritime-decarbonization/

[42] See, CARB's *Potential Future Measures for Reducing Emissions from OGVs 2022 AQMP Mobile Source Working Group April 1, 2021,* the second of two power points found at: https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/ogv-presentations-combined-04-01-21.pdf?sfvrsn=20

sometimes mistakenly focuses on liquefied natural gas (LNG) fuels for OGV. Recent studies show that fossil LNG fuels for OGVs do not significantly reduce GHG emissions from ships, and can increase them.[43] Emission inventories often fail to accurately estimate emissions from gas production, transport, and liquefaction ("upstream emissions"). Similarly, methane losses at gas end use and during ship voyages from "methane slip" are poorly characterized.[44]

All of the above suggests a need for states and the US government to pivot toward more ambitious targets and regulation of OGV emissions and fuels. Action is needed both to achieve deep reductions in greenhouse gas emissions to meet state and national climate goals, but also to prepare for and support IMO implementation regulations needed to achieve global 2040 and 2050 targets.

In the following section, we provide more detail on recent national and international policies to control OGV emissions. This survey is by no means comprehensive. It is offered as evidence that the movement to decarbonize seaborn cargo transport is widespread globally. It also shows that jurisdictions that act to reduce OGV emissions won't do so alone.

COSCO recently announced the first all-electric cargo vessel in use in China on inland river-sea routes.
Photo Courtesy of COCSO Shipping

[43] Compare statements from document cited in prior footnote with: *Working Paper: The Climate Implications Of Using LNG As A Marine Fuel*, 2020. https://theicct.org/publications/climate-impacts-LNG-marine-fuel-2020

[44] See, ICCT, *Fugitive and Unburned Methane Emissions from Ships* (FUMES Study), https://theicct.org/wp-content/uploads/2023/11/ID-64-%E2%80%93-FUMES-ships-Report-A4-60037-FV.pdf

Section 3: **International Policy**

In this section, we describe examples of OGV pollution reduction policy initiatives in nations with large seaborne trade and at the International Maritime Organization. This is not a comprehensive description of the policy momentum currently underway but includes the most prominent developments.

Not addressed here is the parallel international momentum to the development of renewable hydrogen (RH2) supply chains. It is beyond the scope of this study to catalog RH2 policy developments since only some hydrogen policies directly relate to maritime fuels and emissions. But RH2 is likely to be a key feedstock for zero-carbon maritime fuels. Forty-one governments have adopted renewable hydrogen strategies.[45] Actions in the UK, Norway, and the US (e.g. tax credits under the Inflation Reduction Act), in combination with the EU regulations described below, are expected to put strong downward pressure on the price of hydrogen and the cost of zero-carbon maritime fuels.[46] Hence, it is important to acknowledge evolving renewable hydrogen policies as important complements to OGV emission policies.

---

[45] International Energy Agency, *Global Hydrogen Review 2023*, https://www.iea.org/reports/global-hydrogen-review-2023/executive-summary

[46] UMAS, *Cost of zero emissions container freight shipping: a study on selected deep-sea and short-sea routes,* December 2023, https://www.u-mas.co.uk/wp-content/uploads/2023/12/UMAS-2023-Cost-of-zero-emissions-container-freight-shipping-a-study-on-selected-deep-sea-and-short-sea-routes.pdf

International Maritime Organization

In 2018 the IMO set global targets for GHG emissions from vessels, but the target was weak relative to climate mitigation needs.[47] Those targets were significantly strengthened in July 2023. The 2023 IMO action set a net-zero target for emissions from international shipping by 2050. Countries agreed on "indicative checkpoints'' to reduce emissions by at least 20% and striving for 30% by 2030; at least 70% and striving for 80% by 2040. These targets will likely require the average ship to reduce its greenhouse gas (GHG) intensity by ~90% by 2040 (accounting for increased trade volumes).[48] The strategy aims for 5-10% of the energy used in shipping in 2030 to have zero or near-zero GHG emissions. The targets are not quite strong enough to put shipping on a 1.5°C-aligned pathway set by the Paris Agreement, but come close and would achieve very large emission reductions.

These targets will require substantial investments and development in zero-emission technologies on an ambitious timeline. The IMO will develop a set of mid-term implementation measures in 2024-5, potentially to include a low carbon fuel standard and a GHG pricing mechanism (also described as "a greenhouse gas levy and a green fuels mandate").[49]

In the past, the shipping industry tended to oppose GHG controls, but this time major stakeholders, including large shipping fleet owners and operators, supported the IMO action.

While these targets are not legally binding, implementation measures to be adopted next by the IMO will be, since they will be incorporated into an existing international treaty, the International Convention for the Prevention of Pollution from Ships (MARPOL).

The proposed GHG Fuel Standard (GFS) envisions a phased reduction of the GHG intensity of marine fuels. The GFS will be developed by the IMO in the next few years and could come into effect as early as 2027.

The proposed carbon levy would create funding to support low-carbon ships and infrastructure, and economic incentives to reduce carbon emissions. Funding could

---

47 IMO's 2018 target was a 50% reduction in emissions relative to 2008 levels by 2050.

48 Global Maritime Forum, *The implications of the IMO Revised GHG Strategy for shipping,* November 2023, https://www.globalmaritimeforum.org/news/the-implications-of-the-imo-revised-ghg-strategy-for-shipping "Fuel choices: Reaching the GHG reduction targets will require a mix of strategies, including improving energy efficiency and making specific fuel choices. Transition solutions now have a short window for commercial viability. The focus needs to be on scalable zero-emission fuels like e-ammonia, green-methanol, and green hydrogen, as these will need to make up the majority of the sector's fuel use by the late 2030's."

49 As described by Global Maritime Forum: The fuel standard will regulate the GHG intensity of fuel by setting a mandate on the maximum intensity and reducing the limit in set intervals (e.g. one, three or five years). This will send a clear and unambiguous message to shipowners and fuel suppliers that the uptake of near-zero and zero-emission fuels must rapidly increase between now and 2040. Furthermore, it will indicate that both a compatible fleet and sufficient production volumes of fuel need to be able to match this demand. The GHG pricing mechanism will provide a further incentive to reduce emissions. Disbursement of revenue raised through a GHG pricing mechanism can, on the one hand, stimulate the early use of zero-emission fuels and, on the other, contribute towards an equitable transition as funds can be channeled to Small Island Developing States (SIDs) and Least Developed Countries (LDCs).

support an equitable transition for low-income countries transitioning to sustainable shipping practices.

Despite this progress, there are concerns that the next phase of IMO action on OGV GHG emissions could stall, or that implementation measures will not be fully enforceable. But the IMO's 2023 targets and follow-up negotiations on implementation measures are certainly accelerating action on shipping emissions. The momentum could be unstoppable, particularly if there is strong national and subnational support among entities with the power to regulate independently if the IMO process stalls.

European Union

European Union Emissions Trading System

In 2005, the European Union created the European Union Emissions Trading System (EU ETS), a cap-and-trade system to reduce carbon emissions by 62% (from 2005 to 2030).[50] In July 2021, the European Commission created the "Fit for 55" package, a set of legislative proposals aimed at reducing the European Union's GHG emissions by 55% by 2030 (compared to 1990 levels).[51] In June 2023, one key element of this package entered into force - the expansion of the EU ETS to include CO2 emissions from the maritime sector. Beginning in January 2024, the EU ETS will include carbon dioxide emissions from all ships with more than 5,000 gross tonnage entering EU ports. Beginning in 2025, the EU ETS will also cover methane and nitrous oxide emissions from ships. The EU ETS requirements will apply to: (i) 50% of emissions from voyages between EU and non-EU ports; and, (ii) 100% of emissions that occur between two EU ports.

Under this system, shipping operators are annually allotted a certain number of allowances (the right to emit one tonne of carbon dioxide equivalent). Operators are required to submit an emissions report (verified by an independent reviewer) for each ship under their responsibility. Based on this verified report, operators must surrender the number of allowances equal to tons emitted, by September 30 of the following year. There is a 100-euro penalty for carbon dioxide equivalent emissions above the number of allowances surrendered. Penalty revenues support an Innovation Fund, which promotes the development of net-zero technologies, and other measures to decarbonize the maritime sector. There will be a phase-in period such that shipping companies only have to surrender a portion of their emissions (for 2025: 40% of their emissions reported in 2024; for 2026: 70% of their emissions reported in 2025; for 2027 and beyond: 100% of reported emissions).[52]

---

[50] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector/faq-maritime-transport-eu-emissions-trading-system-ets_en

[51] https://cedelft.eu/publications/fueleu-maritime-and-eu-ets/

[52] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en

FuelEU Maritime Regulation

In July 2023, the EU adopted a FuelEU Maritime Regulation based on a proposal from the 'Fit for 55' package. This measure aims to drive demand for low- and zero-carbon fuels in the maritime sector.[53] The regulation calculates carbon dioxide, methane, and nitrogen oxide emissions on a Well-to-Wake basis. The regulation will go into effect on January 1, 2025, and has three key binding targets areas:

1. **Reduction of Energy Intensity:** For ships using EU ports, the annual average GHG intensity of the energy used, measured as GHG emissions per energy unit (gCO2e/MJ), must remain below a threshold value.[54] The FuelEU regulation requires the GHG intensity level to decrease by 2% in 2025, then gradually to 80% by 2050, with a pooling mechanism that allows trading of compliance obligations.This requirement applies to 100% of energy used for voyages between two EU ports, and 50% of energy used on voyages between an EU and non-EU port. Ships that exceed the threshold for GHG intensity must pay a penalty in proportion to their compliance deficit.[55] The rule will encourage bunkering of low GHG fuels at ports.

2. **Use of Onshore Power Supply in EU Ports:** As of 2030, all containerships moored at an EU port for more than two hours must use an onshore power supply (OPS) to cover its electrical needs (also known as "shore power" or "at berth"). The measure includes limited exceptions for incompatibility between the onboard and onshore power equipment. There is a penalty for noncompliance equivalent to EUR 1.5 multiplied by the total electrical power demand at berth and by the total hours of noncompliance.[56] This requirement likely was inspired by California's "At Berth" Regulation.

3. **Incentivize the Uptake of Renewable and Low-Carbon Fuels:** To incentivize the use of Renewable Fuels of Non-Biological Origin (RFNBOs), the GHG intensity of these fuels will be halved for the GHG intensity calculation under the FuelEU regulation.[57] Ships that do not meet the sub-target for RFNBOs must pay a penalty equivalent to the compliance balance. Ships that have compliance deficits for either GHG intensity or RFNBOs target for two or more consecutive years will receive an increased penalty.[58]

The EU action was dramatic and had some global impact. But it also set the stage for even stronger and more universal emissions controls by the IMO.

---

[53] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector/faq-maritime-transport-eu-emissions-trading-system-ets_en

[54] https://www.dnv.com/maritime/insights/topics/fuel-eu-maritime/index.html

[55] https://ww2.eagle.org/en/rules-and-resources/regulatory-updates/fuel-eu-maritime.html

[56] https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/fueleu-maritime-initiative-council-adopts-new-law-to-de-carbonise-the-maritime-sector/; https://ww2.eagle.org/en/rules-and-resources/regulatory-updates/fuel-eu-maritime.html

[57] RFNBOs are renewable fuels which do not contain biomass, landfill gas, sewage treatment plant gas, biogases or other biological sources. The objective of this provision is to avoid deforestation and impacts on food supply associated with increased demand for palm oil, soybean oil, and other feed stocks used in food products.

[58] https://ww2.eagle.org/en/rules-and-resources/regulatory-updates/fuel-eu-maritime.html

Japan

Japan is the fourth-largest exporting partner for the United States and California. California exported $11.6 billion of cargo to Japan in 2022, accounting for the largest share (14.5%) of the exports from the U.S.[59] In March 2023, the government of Japan and the state of California agreed to a "Letter of Intent to Support Port Decarbonization and the Development of Green Ship Corridors." This agreement seeks to deepen cooperation, information sharing, and the discussion of best practices.[60] Consistent with this agreement, ports on the West Coast of North America and Japan are signing individual MOUs to establish green corridors.[61]

In 2020, Japan adopted policies to accelerate efforts to decarbonize energy use in maritime transport and industrial sectors.[62] The strategy lists the shipping industry as one of the 14 promising fields for which Japan will produce action plans: 1) for zero-emission ships; 2) to expand the production of low-carbon fuels; and, 3) to promote technology development to improve the energy efficiency of ships. Notable among the specific measures is the establishment of a 2-trillion-yen ($13.3 billion) Green Innovation Fund, which will support ambitious R&D and implementation efforts over the next 10 years.

The Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT), in cooperation with academia and industry, developed a roadmap of steps to be taken toward 2030 and beyond.[63] In the initial phase, there will be an investment in R&D and pilot projects, development of bunkering guidelines to address issues unique to zero-emission fuels (e.g. green-methanol, ammonia, and hydrogen), and support for facility and equipment, fuel transfer/supply, and emergency response procedures.

MLIT also promotes "Carbon Neutral Port (CNP) Initiatives," including the introduction of zero- and near-zero-emission cargo handling equipment and onshore power supply facilities. In Japan, most refineries, power plants, ironworks, and chemical industries are located in or near maritime ports. CNP seeks to decarbonize: 1) terminal operations; and, 2) industries located in port areas.[64] Currently, six ports, Tokyo, Yokohama, Nagoya, Osaka, Kobe, and Hakata, are designated as pilot ports for these initiatives. Municipal governments are often leading decarbonization collaboratives between ports and nearby heavy industry.[65]

---

[59] U.S. Department of Commerce, TradeStats Express-National and State Trade Data. Computer and electronic products, machinery, chemicals, processed foods, and transportation equipment are exported to Japan. Transportation equipment, chemicals, and machinery are among the products imported from Japan.

[60] The Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT) and the State of California (2023), Letter of Intent to Support Port Decarbonization and the Development of Green Shipping Corridors

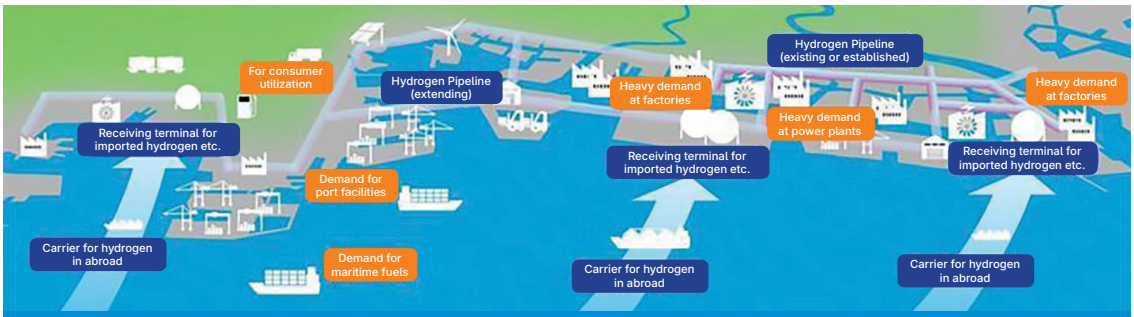
[61] The ports of Los Angeles and Nagoya signed an original agreement in 2020 and updated it to broaden cooperation in 2023. The Port of Los Angeles, Long Beach, Tokyo, and Yokohama established a new partnership following the state-to-country agreement. The Port of Oakland signed an agreement with the Port of Yokohama-Kawasaki in October 2023.

[62] Ministry of Economy, Trade, and Industry (2022), Green Growth Strategy Through Achieving Carbon Neutrality in 2050

[63] Ministry of Land, Infrastructure, Transportation, and Tourism (2020), Roadmap to Zero Emission from International Shipping

[64] Ministry of Land, Infrastructure, Transport and Tourism, Ports and Harbours Bureau：2.4 Carbon Neutral Port (CNP) Initiative

[65] City of Yokohama, Carbon-Neutral Port Initiatives　横浜市 (yokohama.lg.jp)



VESSEL & PORT DECARBONIZATION – PORT OF YOKOHAMA

Yokohama is Japan's largest municipality, located in Kanagawa Prefecture, adjacent to Tokyo. The Port of Yokohama/Kawasaki was opened in 1859 and has supported the surrounding economy through fuel imports, and exports of automobiles, machinery, and many manufactured goods. The waterfront district of Yokohama accounts for about 40 percent of the City's total CO2 emissions.

The Japanese government in 2018 set a "Zero Carbon Yokohama" goal, to reach carbon neutrality by 2050. The City also established and chairs a municipal council for carbon neutrality, involving 200 Japanese local governments. In December 2020, the Port of Yokohama was selected by MLIT as one of the seven ports in Japan to work on the formation of a carbon-neutral port. In response to this, the City created "the Yokohama CNP Council" that involves the representatives of the sector in the waterfront area, and national government in August 2022.

The City played a key role in achieving wide-area coordination. In November 2021, the City concluded an agreement with ENEOS Corporation, Japan's largest oil company. The agreement strives to achieve a "hydrogen society" by developing and implementing a hydrogen supply infrastructure using pipelines. In July 2022, Yokohama and Kawasaki agreed to collaborate for expanded use of hydrogen and other types of next-generation energy.

The initiative in the port of Yokohama aims for next-generation energy conversion at waterfront areas. Onshore power supply and low-carbon fuel bunkering are being introduced as the first step. In the next phase, it will develop the energy conversion at port terminals, including the construction of pipelines and storage tanks for hydrogen and synthetic methane.

Private companies in Japan are also promoting the decarbonization of ocean-going vessels. In 2021, the Japanese Shipowners' Association (JSA) announced the Japanese shipping industry would achieve net-zero shipping emissions GHG by 2050. This will require a shipbuilding investment of about $10 billion annually for 25 years.[66]

[66] Japanese Shipowners' Association (2021), Japanese Shipping Industry Announces Challenge of 2050 Net Zero GHG (jsanet.or.jp)

China

In 2019, China's coastal shipping sector emitted about 45 million tonnes of CO2 or roughly 4.5% of total CO2 emissions from China's transportation sector. With no additional policies, CO2 emissions from China's domestic coastal shipping would more than triple to 162 million tonnes in 2060.[67] At the 75th UN General Assembly in September 2020, Chinese President Xi Jinping announced that China's overall CO2 emissions will peak by 2030 and that carbon neutrality will be reached before 2060, and the country is making efforts to attain this goal through national and private sector actions.

In 2022, along with four other nations, China proposed the creation of an International Maritime Sustainability Funding and Reward (IMSF&R) mechanism that, based on benchmarks for CO2 emissions, would collect funding contributions from ships with actual CO2 emissions above the upper benchmark level and reward ships with CO2 emissions below the lower benchmark level.[68]

Several efforts are underway in China to support research and innovation to reduce emissions from shipping.

- China State Shipbuilding Corporation (CSSC), in collaboration with DNV, has established a Future Ship Joint Innovation Centre in Shanghai. The Centre will allow both companies to cooperate on the ship and offshore field technical innovation, advance in decarbonization and digitalization transformation, and provide technical support and solutions to the maritime industry.[69]
- The "Action Plan for Electrify Fujian Province", released in June 2023, offers grants/subsidies for a wide range of shipping decarbonization efforts including:
    - Research institutes
    - Electric ship demonstration projects
    - Ship battery manufacturing
    - Electricity supply for battery-powered ships
    - Battery swap stations
    - Low-cost financing for purchasers of battery and fuel-cell-powered ships.

Chinese shipyards are engaged in the construction of ships able to use low- or zero-carbon fuels. Some Chinese ports (including Shanghai and ports on the Yangtze River) are installing shore power infrastructure. Shore power requirements will expand nationwide in 2024, enforced via fines for ships unable to connect to onshore grids. For example, in 2023, the CMA CGM Group and Shanghai International Port (Group) Co., Ltd. ("SIPG") signed a long-term strategic collaboration to develop the mass-scale use of

[67] Decarbonizing China's coastal shipping: The role of fuel efficiency and low-carbon fuels - International Council on Clean Transportation (theicct.org)

[68] https://www.ajot.com/news/article/cssc-and-dnv-unveil-future-ship-joint-innovation-centre-in-shanghai

[69] https://www.dnv.com/news/cssc-and-dnv-unveil-future-ship-joint-innovation-centre-in-shanghai-244823

"cold ironing" technology (or "Shore Power") for containerships at the Port of Shanghai.[70] Corporations in China are beginning to produce green methanol.[71]

■ Republic of Korea

Republic of Korea's Ministry of Oceans and Fisheries (Mof) and the 2050 Carbon Neutrality & Green Growth Commission have announced the "Strategy for Decarbonization of International Shipping" to decarbonize the shipping sector by 2050, with a focus on four areas:

- convert ships owned by national shipping companies into ships that use eco-friendly fuels,
- encourage timely investment in the transition to eco-friendly fleets,
- develop eco-friendly technology and expand infrastructure for future fuels, and
- establish zero-carbon shipping routes.[72]

MOTIE, in collaboration with the Korea Institute of Energy Research (KIER), established an alliance involving 13 private firms and five public institutions with long-term aims to achieve carbon neutrality. The specific action plans of the alliance will be devised and implemented by the participating private companies. The firms agreed to jointly develop technologies with regard to ammonia production and transportation, extraction of hydrogen from green ammonia, and use of the extracted hydrogen for gas turbines and fuel cells.

■ Singapore

Maritime and Port Authority of Singapore (MPA), in consultation with industry partners, developed a Blueprint to move decisively on maritime decarbonization. The Port of Singapore leads the Maritime Singapore Green Initiative to promote the decarbonization of shipping. The initiative includes four programs: Green Ship Program, Green Port Program, Green Energy and Technology Program, and Green Awareness Program. These are voluntary programs designed to recognize and provide incentives to companies that adopt clean and green shipping practices, such as reductions and/or waivers in ship registration fees, tonnage taxes, and port dues for ships that exceed IMO environmental regulatory standards or use low- or zero-carbon fuel.

---

[70] https://logistics-manager.com/cma-cgm-and-the-port-of-shanghai-accelerate-their-decarbonisation-journey/

[71] *Chinese carmaker plans world's biggest green hydrogen-to-methanol project,* https://www.hydrogeninsight.com/production/chinese-carmaker-plans-world-s-biggest-green-hydrogen-to-methanol-project/2-1-1586770; *Maersk's green methanol production ambition expands to China*, https://renewablesnow.com/news/maersks-green-methanol-production-ambition-expands-to-china-776658/

[72] *Toward Green Shipping by 2050, 2023 National Action Plan,* https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/NAP/R.O.K%20National%20Action%20Plan%20-%20Toward%20Green%20Shipping%20by%202050.pdf

The Port of Singapore accepts various projects conducted by international private companies. An example of cooperation between Singapore and China is the announcement in November 2023 of plans to supply a B24 biofuel blend to Orient Overseas Container Line (OOCL).[73] The fuel delivery, arranged by KPI OceanConnect's team in Singapore and supplied by barge, was received by OOCL's container vessel while at port in Singapore. In addition, there are several plans with other ports to establish green trade corridors.

Singapore commissioned its first dedicated methanol bunker vessel, the MT Maple, in December 2023. The ship was built by Japan's Sasaki Shipbuilding as part of an agreement involving Global Energy Trading and its subsidiary Stellar Ship Management Services.[74] Singapore plans to adopt a domestic harbor craft regulation requiring all newly licensed harbor craft vessels to be fully electric, B100-capable, or compatible with net-zero fuels by 2030.[75] Singapore is developing plans and financing for blue/green ammonia[76] and green methanol bunkering.[77] [78] [79] Singapore has developed new regulatory licensing frameworks for the supply of biofuels, with frameworks for methanol and ammonia forthcoming.[80] [81] [82]

Singapore is home to the largest bunkering port and a global leader in the maritime energy transition. The proximity of vessels to portside communities is a clear reminder of the need for zero-emission fuels and technologies to reduce shipping's health impacts.

---

73 KPI OceanConnect supplies OOCL with biofuel blend marking a significant milestone in their sustainability journeys | AJOT.COM

74 The Maritime & Port Authority of Singapore has established a working group to introduce a new bunkering procedure for the safe handling and delivery of methanol as a marine fuel to ships refueling in the port of Singapore. https://maritime-executive.com/article/singapore-s-first-dedicated-methanol-bunker-ship-is-commissioned

75 Maritime Singapore, *Decarbonization Blueprint, Working towards 2050,* 2022, https://www.mpa.gov.sg/docs/mpalibraries/mpa-documents-files/sustainability-office/mpa-decarb-blueprint-2050a.pdf

76 https://www.mpa.gov.sg/media-centre/details/singapore-launches-next-stage-of-selection-of-low--or-zero-carbon-ammonia-power-generation-and-bunkering-project-developer

77 https://www.mpa.gov.sg/media-centre/details/expression-of-interest-for-the-supply-of-methanol-as-a-marine-bunker-fuel-in-the-port-of-singapore

78 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/shipping/072723-singapore-completes-first-methanol-bunkering-learnings-to-be-presented-to-imo

79 https://www.reuters.com/markets/commodities/singapore-port-authority-seeks-methanol-bunker-supply-proposals-2023-12-14/

80 https://www.reuters.com/markets/commodities/singapore-port-authority-seeks-methanol-bunker-supply-proposals-2023-12-14/

81 https://www.mpa.gov.sg/port-marine-ops/marine-services/bunkering/biofuel-bunkering

82 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/shipping/072723-singapore-completes-first-methanol-bunkering-learnings-to-be-presented-to-imo

India

In 2021 India released a plan, Maritime India Vision 2023. Approved by Prime Minister Modi, the plan calls for electrification of port equipment, shore power infrastructure, and increased use of renewable energy.[83] Initiative 9.3, "Drive adoption of Multiclean fuels," initially focused on "Electric, CNG, LNG" with hydrogen, ammonia, methanol, batteries and fuel cells addressed.

Recently the agency and port operators appear more focused on renewable hydrogen and ammonia. In guidelines released by the shipping Ministry in May 2023, India set a target of 2035 for setting up green hydrogen fuel bunkering and refueling facilities at major ports.[84] India's Ministry of Ports, Shipping, and Waterways (MoPSW) has identified three major ports — Deendayal Port (Kandla), Paradip Port, and Tuticorin Port — as hubs for green hydrogen, green ammonia, and green methanol in the next seven years. The ports will develop infrastructure to facilitate storage, handling, and bunkering of green hydrogen, green ammonia, and their derivatives.[85] The Deendayal Port Authority in Kandla, Gujarat, released a global call for applications to develop a green hydrogen hub at the port. The call seeks 7 million metric tons per annum (MMTPA) of green ammonia production.

India has established a National Centre of Excellence for Green Ports and Shipping (NCoEGPS)[86] which supports the development of regulatory frameworks and alternative technology road maps for Green Shipping. The objective is to foster carbon neutrality in India's shipping stores. The Centre is based at The Energy and Resources Institute (TERI).[87]

WindWings—wind powered cargo ships—were designed within a partnership between Cargill, BAR Technologies and MC Shipping.
Photo Courtesy of Cargill

---

83 https://shipmin.gov.in/content/maritime-india-vision-2030

84 *India Plans to Roll Out Green Fuel Bunkering at Top 12 Seaports*, https://maritime-executive.com/article/india-plans-to-roll-out-green-fuel-bunkering-at-top-12-seaports

85 https://indiashippingnews.com/india-sets-deadline-of-2035-to-establish-green-hydrogen-bunkering/?utm_source=news-letter&utm_medium=email&utm_campaign=E-Newsletter+11+May+2023%2C+India+Shipping+News&sender_ctype=email&sender_campaign=egXlp6&sender_customer=qjOX5m7, May 11, 23.

86 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1877297

87 https://www.teriin.org/

Rendering of cargo ship *With Orca* to be powered solely by green hydrogen, wind, and on-board batteries for use in the North Sea.

Photo: Courtesy of Egil Ulvan Rederi

■ Private Sector initiatives

In addition to government and maritime port initiatives, many large private sector investments in zero-carbon shipping are underway. The following is just a sampling of these developments. Maersk and other companies have ordered the construction of more than 125 new ships equipped to run on zero-carbon green-methanol fuels.[88] Maersk appears to have sparked a shift in the global industry. According to UNCTAD[89] 21% of ocean-going vessels currently on order have the potential to operate on cleaner fuel alternatives.

A supply chain for low- or zero-carbon fuels is under development. For example, Maersk also has signed contracts for very large amounts of green methanol fuel from suppliers in China and the EU. Maersk is one of 10 major shipping companies that have contracted for green methanol to be used as fuel in OGVs.[90]

Major cargo owners have committed to shifting ocean freight to vessels powered by zero-carbon fuels. Facilitated by the Aspen Institute, the Cargo Owners Zero Emission Vessel Initiative (CoZEV) is a group of brands that aim to progressively switch all of their ocean freight to vessels powered by zero-carbon fuels by 2040. Current member companies include: Amazon, Beiersdorf, Brooks, Dupont, Electrolux, ETTLI Zentrale & Großhandel, Frog Bikes, Ikea, Inditex, Michelin, Moose, Ohana Coffee Tea & Love, Patagonia, Philips, REI Co-op, Sisley Paris, Target, Tchibo, Unilever. Maersk is developing a maritime book and claim system in collaboration with McKinney Møller Center for Zero Carbon Shipping, RMI, Danish Shipping, and Maersk Oil Trading, with funding from the Danish Maritime Fund. The methodology aims to allow the benefits and costs of decarbonization to be shared across the maritime supply chain through a tokenized system that allows for swapping emissions among users.

For more information and citations for corporate, maritime port, and other voluntary commitments to reduced vessel emissions see accompanying spreadsheet.[91]

---

88 NY Times, *Shipping Contributes Heavily to Climate Change. Are Green Ships the Solution?* October, 30 2023 https://www.nytimes.com/2023/10/30/business/economy/shipping-climate-change-green-fuel.html.

89 United Nations Conference On Trade And Development, *Review of Maritime Transport 2023*. https://unctad.org/system/files/official-document/rmt2023_en.pdf

90 Green Car Congress, *Equinor to supply Maersk with green methanol for the first methanol-enabled container vessel, September 2023; https://www.greencarcongress.com/2023/09/20230909-maersk.html;* Bloomberg, *Shipping Giant Maersk Plans Shift to Green Fuel in Effort to Ditch Oil,* March 10, 2022, *https://www.bloomberg.com/news/articles/2022-03-10/maersk-finds-partners-to-make-green-fuel-in-plan-to-ditch-oil?cmpid=BBD013023_TRADE&utm_medium=email&utm_source=newsletter&utm_term=230130&utm_campaign=tradeMaersk secures green e-methanol for the world's first container vessel operating on carbon neutral fuel,* August 2021, https://www.maersk.com/news/articles/2021/08/18/maersk-secures-green-e-methanol See also, *The prestigious North-C-Methanol project reduces CO2 emissions by 140,000 tonnes annually and produces 44,000 tonnes of green methanol*, https://www.cnc3.co.tt/proman-to-build-worlds-largest-green-methanol-plant/#google_vignette

91 *Catalog of Policy & Regulation Initiatives to Reduce Ocean Going Vessel Emissions,* available at https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/ocean-going-vessel-decarbonization


Photo courtesy of the Port of Los Angeles

Section 3: **Policy Recommendations**

In this section, we describe a menu of policy recommendations for U.S. federal and state governments and a set of voluntary actions for the private sector. We focused here on California, given its prominent role in U.S. maritime import and export trade.

We emphasize a "suite of policy options." While some of these ideas could be implemented together, or staged over time, some measures may contradict or be incompatible with others.

■ Policy Recommendations for California State Government

Our policy recommendations start with California for several reasons. The State agencies have long experience with maritime emission issues. They already have statutory authority to adopt many of the policy changes described below. If new legislation action is needed, the State Legislature is relatively nimble compared to the US Congress and less affected by national politics.

- **Establish an in-transit rule for vessel GHG emissions and criteria pollutants** Absent federal action to control OGV GHG emissions, CARB should be able to adopt regulations to establish market-based requirements that gradually reduce the carbon intensity of marine fuels and criteria pollutant emissions of ships serving CA ports or traveling in coastal waters. One option is for the state to impose limits on GHG emissions and criteria pollutants of ships traveling to and from California maritime ports ("Intrastate Marine Travel"). There is precedent for this in CARB's 2009 California regulations to reduce emissions of sulfur and NO_x

from ships operating in coastal waters.[92] This action likely influenced the U.S. government and IMO to adopt national and global regulation of emissions from vessels.[93] The main elements of this measure would include the following.

- The state would set a baseline for uncontrolled emissions, measured on well-to-wake GHG emission intensity for energy used by ships calling at CA Ports. This baseline approach is used for other transportation GHG emissions and includes declining annual standards, referred to as the CI benchmark.
    - Separate GHG and criteria pollutant benchmarks could be established such that all obligated parties (OGVs operating within the designated areas) would have to comply with both the required CI reductions and the criteria pollutant reductions.

- Every ship entering CA ports must report emissions (and operating parameters such as speed and fuel type) when operating in CA waters and would have to achieve GHG and criteria pollutant emission reductions by a certain percentage below the baseline by a target date. The targets would gradually decline over time. Ships that meet the targeted GHG and criteria pollutant deductions could sell the surplus emission reductions to other ships that are not able to reduce emissions to the required level (e.g. due to age of the ship and expected operational life).

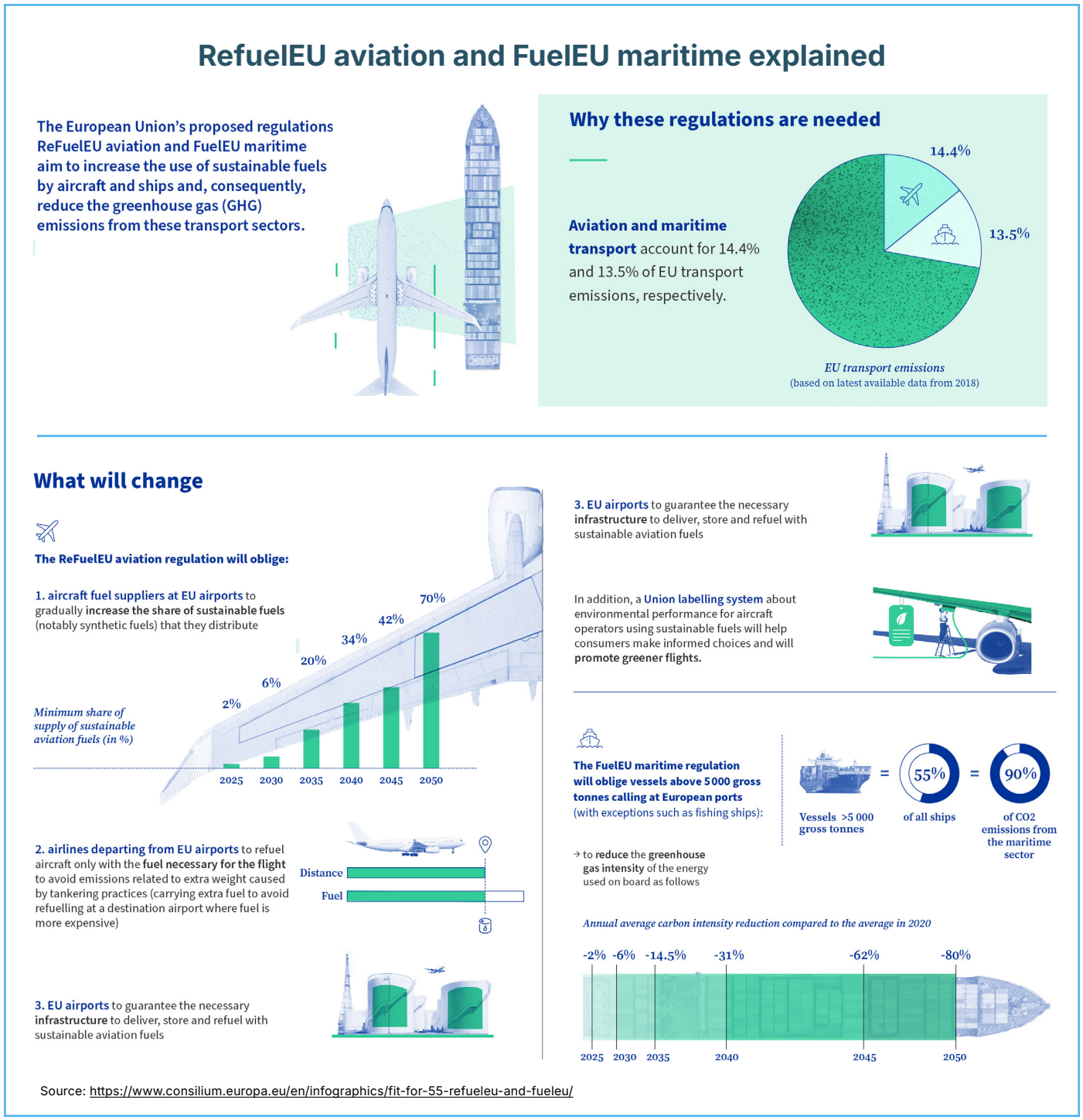
- A California regulation could parallel the design of the FuelEU Maritime rule, which sets an absolute limit on carbon intensity of energy, differentiated by origin and destination. For example, a CA in-transit rule could use a similar well-to-wake carbon intensity measurement protocol and limits. Given that many regions of the state are in nonattainment for national ambient air quality standards, the rule should include criteria pollutants as well. Like FuelEU, a CA rule could be applied to 100% of energy used on voyages and port calls between CA ports, and 50% of energy used on voyages into or out of California ports from other destinations. The scope of the 100% application could be expanded to voyages between CA and other Pacific state ports (WA, OR, HI, BC), and potentially between West Coast/Pacific and EU ports (where authorities have adopted reciprocal rules). The in-transit rule should meet the Science-Based Targets Initiative of reaching a 96% emission reduction target by 2040.[94]

The in-transit rule should meet the Science-Based Targets Initiative of reaching a 96% emission reduction target by 2040

[92] Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline. Title13, California Code of Regulations (CCR) §2299.2 and title 17, CCR §93118.2; https://ww2.arb.ca.gov/ogv-fuel-regulation-and-rulemaking-documents.

[93] The authority of California to regulate emissions from ships operating off its coast was tested and approved in a series of decisions by the United States Court of Appeals for the Ninth Circuit. Pacific Merchant Shipping Association v. Goldstene, 639 F.3d 1154 (9th Cir. 2011); PMSA *v. Goldstene*, 517 F.3d 1108 (9th Cir. 2008).

[94] https://sciencebasedtargets.org/resources/files/SBTi-Maritime-Guidance.pdf



Source: https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/

- The regulation could be accompanied by port fees and noncompliance penalties that would create a fund to support retrofit and new construction of low-carbon OGVs and to establish or increase production of low or zero-carbon liquid fuels.

- The State could design the system in collaboration with other subnational governments (e.g. Pacific Northwest states, Canadian Provinces, and Mexican states).

- State rules should include rigorous well-to-wake measurement rules that account for upstream fugitive emissions, emissions associated with fuel production and use (e.g. methane leaks associated with fossil gas supplies used in the production of liquefied natural gas, emissions associated with liquefaction and regasification, and methane lost from boil-off during voyages).

  West Coast state action might, in effect, expand the impact of FuelEU to portions of the Pacific transoceanic cargo sector that are not subject to the FUEL EU regulations.

- **Research and explore options to expand the Low Carbon Fuel Standard program to include OGV bunker fuel and low- or zero-carbon alternatives.** Currently, conventional fuels used for military vehicles, aircraft, ocean-going vessels, and locomotives are exempt from meeting the carbon intensity standards for LCFS.[95] The LCFS stimulated the production of alternative energy supplies for road transport including biodiesel and renewable diesel. Today these fuels collectively supply more of the California on-road diesel market than petroleum diesel fuel. The LCFS also has provisions to supply LCFS crediting to electricity supplies for shore power.[96] If eligibility for marine vessel use is established, LCFS credits could be provided to other fuels such as green methanol, ammonia, and green hydrogen.

Green hydrogen use in fuel cells represents true zero emission fuel for OGV use. Hydrogen derived fuels such as e-ammonia and e-methanol will also be essential as intermediaries and fuel carriers

The LCFS regulations could be amended in several ways to expand the availability of low- and zero-carbon OGV fuels in California. Some ways to do this are apparent from the treatment of aviation fuels under the LCFS. Alternative Jet Fuel (AJF) production became eligible under the LCFS as an opt-in fuel in 2019 (i.e. become eligible as a credit generator).[97] This appears to have stimulated an increase in AJF production. CARB also recently proposed to eliminate the exemption for aviation fuel used in intrastate flights from LCFS regulation, starting in 2028. This

---

95 https://rmi.org/understanding-californias-low-carbon-fuel-standards-regulation/. Inclusion of bunker fuels in CA's LCFS and GHG cap-and-trade regulations was discussed in draft 2018 Technology Assessment on ocean going vessels. https://ww2.arb.ca.gov/sites/default/files/classic/msprog/tech/techreport/ogv_tech_report.pdf?_ga=2.176263653.1539937694.1701475865-233560686.1686860641https://ww2.arb.ca.gov/sites/default/files/classic/msprog/tech/techreport/ogv_tech_report.pdf?_ga=2.176263653.1539937694.1701475865-233560686.1686860641

96 CARB. Ocean-Going Vessels At Berth Regulation. https://ww2.arb.ca.gov/our-work/programs/oceangoing-vessels-berth-regulation.

97 In the current LCFS rulemaking, CARB has proposed an Intrastate LCFS for aviation. Under the current LCFS regulation, airlines are exempted from the LCFS program but may generate credits that can be used by obligated parties for alternative jet fuel that is uplifted in California. Under the proposed LCFS regulation, point-to-point California flights would generate deficits for the fuel suppliers to the airlines.

would make fossil jet fuel used in intrastate flights an obligated fuel that triggers compliance obligations under the program.[98]

There are several options to be considered: low- or zero-carbon marine fuels could be allowed to opt in to become a credit generator;[99] or bunker fuel supplied in California could become fully subject to the LCFS requirement (deficit generator).

Low- or zero-carbon marine fuels could be allowed to opt in to become a credit generator, or bunker fuel supplied in California could become fully subject to the LCFS requirement.

Research is needed to understand the benefits, costs, and practicality of these options. The eligibility/opt-in path seems the most feasible. It would create incentives for refiners to gradually reduce the carbon intensity of bunker fuel production, via the generation and sale of credits from the use of low-carbon fuels in OGV. After an LCFS rulemaking change to make OGV fuel use eligible to generate credits, a fuel producer might initiate an opt-in through an application under the California Code of Regulations §95488 process for establishing a Fuel Pathway.

Oregon, Washington, and British Columbia have all adopted clean fuel standards that are similar to California's.[100] California could lead a regional effort to harmonize these programs concerning OGV fuel production and use, especially regarding green methanol production.

- **Establish a cap-and-trade regulation for OGVs serving CA ports:** The following is only a sketch for a state OGV emission cap-and-trade system, offered here as an alternative to the LCFS, and in-transit rule options discussed above. The intent here is to provide a general idea of how a cap-and-trade system would operate, to stimulate discussion and test feasibility.

  The options include: 1) add large vessel GHG emission to the existing GHG cap-and-trade system, by which vessel emissions would be treated like stationary sources; or, 2) create a separate cap and emission allowance market for large vessels.

  The first option would likely stimulate the lowest-cost GHG emission reductions and generate revenues for the state's GHG Reduction Fund. But ship emission control strategies may be too different from stationary GHG sources in cost and temporal

---

98 California Air Resources Board, *Staff Report: Initial Statement of Reasons*, December 19, 2023, page 26-27, 116, https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2024/lcfs2024/isor.pdf

99 In a statement dated August 28, 2023 the AB32 Environmental Justice Advisory Committee recommended that CARB: Consider the inclusion of intrastate jet fuel and marine fuels as a deficit generator and provide analysis of this option as part of the LCFS. https://ww2.arb.ca.gov/sites/default/files/2023-08/EJAC%20DRAFT%20Low%20Carbon%20Fuel%20Standard%20Recommendations%20Version%202%20082823.pdf

100 Oregon Clean Fuels Program: https://www.oregon.gov/deq/ghgp/cfp/pages/cfp-overview.aspx; Washington state: https://ecology.wa.gov/air-climate/reducing-greenhouse-gas-emissions/clean-fuel-standard; British Columbia LCFS, https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels

availability, such that adding ships to the existing cap-and-trade systems might drive ship owners/operators to comply exclusively by purchasing low-cost allowances from other categories of sources, or by shifting bunker fuel production and sales offshore. This might result in no emission reductions from the shipping sector[101] and perpetuate environmental justice inequities for people living near ports who are exposed to conventional air pollutants co-emitted with GHG emissions. Another problem is that emission offsets are under suspicion for their emission reduction integrity (additionality).

These objections might however be addressed by moving simultaneously to adopt new controls on conventional emissions from OGV. See below for a range of possibilities including: statewide vessel speed reductions near coastlines; adoption of Tier III and IV engine standards for OGVs; access fees that incentivize port calls by ships using cleaner engines and fuels; and funding port infrastructure to reduce conventional and GHG emissions.

If it is not practical to include OGV emissions in the existing GHG cap-and-trade system a second option could be to establish a separate cap and allowance pool in which vessel-specific allowances are traded exclusively within the shipping industry. Regarding the second option, elements of such a regulation would include:

- Establish a declining cap on such vessel emissions in U.S. territorial waters;
- Allocate allowances to ship operations based on actual port calls and estimated time operating in waters off the coast of CA (e.g. 200 miles);
- Ship owners or operators must retire allowances equal to the estimated emissions resulting from their port calls, with an option to trade allowances with other ship owners.
- Special provisions may be needed for ships that only occasionally travel to CA Ports.

Revenues from the shipping cap and trade system could be managed as part of the state's GHG Reduction Fund. Additional research is needed on this topic.

- **OGV Reporting data collection requirements:** Establish a monitoring, reporting, and verification (MRV) mechanism to collect fuel consumption and emissions data from all large commercial ships that use CA ports. This will build a baseline for the management of other policy initiatives including, as discussed below:
  - a state GHG cap-and-trade system for emissions from large vessels calling at California ports;
  - extension of the Low Carbon Fuel Standard (LCFS) regulation to OGV fuels not currently covered (e.g. green methanol, green hydrogen, and ammonia); and/or,
  - port entry fees or taxes differentiated by the carbon Intensity of cargo transport.

[101] GHG emission could potentially increase if refinery outputs are shipped to other nations which produce bunker fuel which is then sold to ships calling at CA ports.

One option would be to modify California's existing Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (MRR) to address emissions from ocean-going vessels calling at California ports. Where possible, however, the reporting requirement should reflect reporting requirements imposed in the European Union's Monitoring, Reporting, and Verification system.[102]

- **Revise California's Climate Scoping Plan Revision to address OGV Emissions:** The 2022 Scoping Plan refers to recently adopted shore power requirements for ships at berth. It also used modeling assumptions regarding potential future use of hydrogen fuel cell technology in OGVs.[103] Modeling assessed an OGV target described as:

  > *"10% of OGVs utilize hydrogen fuel cell electric technology by 2035. Rest of OGVs fuel demand not met in 2035 because non combustion alternative not available (sic)."*

  This analysis should be updated in the 2027 Scoping Plan, or as a stand-alone and updated CARB Technology Assessment for OGV technologies. Fuel cell technology is only one of the ways to reduce GHG emissions from OGVs, and may not be available for large ships in the near term. The next plan could more broadly address options for GHG emissions from large vessels, including:
  - Use of zero-carbon liquid drop-in fuels either as primary fuel, co-fired blends, or for exclusive use in transit near coastlines;
  - Use of batteries for short-haul OGV routes and operations in transit through coastal waters;
  - Vessel speed reductions;
  - Production of and supply chain infrastructure for low- or zero-carbon liquid fuels for OGVs.
  - Use of wind propulsion systems.

  CARB's 2027 Scoping Plan could develop strategies that differentiate options among different vessel types and set targets for near-term progress toward a goal of zero-carbon OGV operations.

---

[102] SAFE-T is a software tool that could be used to support policy options discussed in this paper. SAFE-T is a web-based suite of tools that allow users to evaluate emissions and greenhouse gas reduction strategies for shipping. SAFE-T was built from a blend of literature analysis, evaluation of comparable tools, input from stakeholders, and examination of key subject matters. SAFE-T is built on international standards and methodologies. Fuel-based emissions in the SAFE-T tools are based on the ISO 14083 and EN 16268 standards. http://safet.io

[103] See, https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-c-ab-197-measure-analysis.pdf Page 3.

- **State Port Access fees:** While port access fees are currently set by individual port authorities, the state could apply a supplemental or additional port access fee differentiated by carbon intensity of ship engines, with revenues used to incentivize low- or zero-carbon ship retrofits, new builds or California-based zero-carbon fuel production and fueling infrastructure for OGVs.

- **Vessel Speed Reduction:** Ports in California currently offer financial incentives for vessels that voluntarily reduce speed in coastal waters. This is offered partly as a means to reduce ship strikes on marine mammals, and partly to reduce emissions of conventional pollutants and GHG emissions. The state could establish a mandatory statewide requirement for speed reductions for ships whose emissions do not increase at low speeds.[104]

- **Revise State Implementation Plan:** In the next revision to the State's SIP, California should include a detailed plan to secure 100% emission reductions from OGVs calling on CA ports by 2040. This would likely include a combination of research, incentives, regulatory controls, and zero-carbon fuel and electricity production to support a transition to zero-carbon waterborne freight operations.[105]

- **Address OGV emissions in the preparation of the 2025 state Mobile Source Strategy under Senate Bill (SB) 44:** The 2020 **Mobile Source Strategy (MSS)** included strategies to push for the adoption of Tier 4 marine standards by the U.S. EPA and IMO and support zero-emission OGV demonstrations[106] The 2020 MSS includes statements of skepticism regarding zero-carbon fuel options:

> *Biofuels, renewable hydrogen, and other hydrogen-derived fuels such as ammonia, methanol, batteries, and fuel cells are being considered as potential fuel choices for zero-emission vessels. As the zero-emission technologies for marine vessels are still at an early stage and technological feasibility needs to be proven, CARB did not incorporate these strategies in the current 2020 MSS scenario. CARB will consider these strategies in future updates to the MSS as more information becomes available.*

---

[104] Tier III and IV engines, which are not yet available for ocean going vessels, would be equipped with Selective Catalytic Reduction (SCR) and flue gas recirculation (EGR) systems to control NOx emissions. These systems do not operate well at slow vessel speeds, and may need to be exempted from VSR requirements.

[105] California's 2022 State Implementation Plan (SIP) Strategy forecast plans to evaluate regulatory actions to reduce GHG emissions from ocean-going vessels, including use of methanol, ammonia, etc. The 2022 SIP also described CARB's intent to explore financial incentives to encourage ships to use cleaner engines or fuels when operating out of California seaports. The SIP states that CARB and other state agencies should work in collaboration with port authorities, terminal operators, and ship owners/operators to improve the OGV part of the emission inventory. CARB. State Implementation Plan Strategy, 2022. pg. 119; *CARB, Draft 2022 Scoping Plan, appendix H, AB 32 GHG Inventory Sector Modeling, May 2022.* https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf

[106] https://ww2.arb.ca.gov/sites/default/files/2021-12/2020_Mobile_Source_Strategy.pdf, page 148.

Technologies to control conventional pollution and GHG from ships have advanced more quickly than was expected in 2019. Major OGV companies have begun to procure green methanol fuel supplies and methanol-ready vessels. While advocacy for action by IMO and the U.S. EPA should continue, the state should not wait for those entities to act, and the next MSS (prepared pursuant to SB44) should include a more robust assessment of zero-carbon fuel options for OGVs.

- **Engage with U.S. EPA and IMO on OGV decarbonization:** CARB's experienced staff and leadership have the potential to move IMO and EPA toward effective national and international controls on OGV emissions. Engagement could take several forms and could help the state prepare for any controls established by IMO and EPA, or impose its controls if those entities do not adopt strong regulatory actions. Action, or statements of intent by CARB could help establish precedents for EPA and IMO action. The following are some specific engagement options.
    - Commit staff to participate in negotiations and research leading to the adoption of interim implementation measures by the IMO, including: 1) the "impact assessment" to be conducted in 2024; and, 2) the design of fuel standard and pricing mechanisms (2024-2025).
    - CARB can petition the U.S. EPA to make a "Harm" finding under the federal Clean Air Act regarding OGV GHG emissions. This could prompt the U.S. EPA to move forward to control OGV emissions. That engagement would also complement or lay the foundation for U.S. implementation action under future IMO rules.
    - Urge federal agencies to adequately fund the Marine Highway Program and other federal programs to decarbonize "Jones Act" ships moving between U.S. Ports.
    - A 2021 CARB workshop identified a series of U.S. EPA actions that would help reduce NOx and particulate matter emissions from OGVs, some of which might be combined with GHG emission controls or new and existing ships. These include:
        - New engine standards Tier II+ (retrofit or remanufacturing kits), Tier III and IV;
        - Optional engine standards based on verified retrofit control technologies;
        - Limits on port access for older vessels (e.g., Tier 0 & Tier I); and,
        - Development and demonstration of retrofit control technologies including efficiency measures, wind propulsion and hull design improvements.[107]

[107] This idea was also mentioned in a powerpoint presentation by South Coast Air Quality Management Plan, " 2022 AQMP OGV Working Group," in April 2021. https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/ogv-presentations-combined-04-01-21.pdf?sfvrsn=20

- **Revise CARB's 2018 Draft Technical Assessment: Ocean-Going Vessels:** Some useful financial incentive options are discussed in the draft Assessment,[108] but the final Assessment should include a much more detailed review of the current landscape of GHG reduction options for OGVs.

- **Convene Yokohama-like port & vessel decarbonization collaboratives in San Pedro and SF Bay regions:** The objective could be to coordinate efforts by ports (maritime and aviation), terminal operators, shipping lines, refineries, wastewater treatment plants, local government, and industry associations to plan for port, ship, and heavy industry decarbonization. For example, the production of green hydrogen is needed for refinery operations, the production of alternative aviation fuels, OGV fuels, and, potentially, port cargo handling equipment and long-haul trucking. Carbon capture capacity may be needed for the production of green-methanol and other low-carbon liquid fuels.

- **Fund zero-carbon port OGV fueling infrastructure and vessel fuel production:** Legislation could establish funding for public-private partnerships to establish a California-based supply chain for zero-carbon ship fuels. This could be developed in collaboration with the federally funded Hydrogen Hub in California (ARCHES).

- **GHG inventory changes:** California could modify and improve its GHG inventory to include and better reflect GHG emissions from maritime vessels.[109] The California Air Resources Board (CARB) reports that the combustion of international bunker fuel was responsible for approximately 13 million tons of CO2e emissions[110] [111] These emissions are currently excluded from state emissions accounting, on the argument that they reflect the emissions of an interwoven global trade network. CARB's 2021 California Ocean-Going Vessels Emissions Inventory (March 2022) only includes emissions from fuel combustion within 100 nautical miles of the California coastline, which amounts to approximately 2.2 million tons of CO2e per year from OGVs. Other data suggest that OGVs emit about 3.5 million tons of CO2 and 50 tons of methane (about 4200 tons of CO2e on a 20-year basis) annually.[112] The numbers are contradictory, perhaps because methane emissions are routinely underestimated (especially regarding

---

[108] Draft Technology Assessment Ocean-Going Vessels, May 2018. https://ww2.arb.ca.gov/sites/default/files/classic/msprog/tech/techreport/ogv_tech_report.pdf?_ga=2.176263653.1539937694.1701475865-233560686.1686860641

[109] In a 2021 Workshop, CARB staff discussed the option to improve the OGV emission inventory. https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/ogv-presentations-combined-04-01-21.pdf?sfvrsn=20

[110] CO2 equivalent, or CO2e, captures the GHG influence of CO2 as well as other emissions, such as methane (CH4) and nitrous oxide (N2O).

[111] CARB Greenhouse Gas Emission Inventory, 2023.

[112] California Air Resources Board, *2021 California Ocean-Going Vessels Emissions Inventory* Table 14, page 30, https://ww2.arb.ca.gov/sites/default/files/2022-03/CARB_2021_OGV_Documentation.pdf

upstream methane emissions from LNG cargoes).[113] The inventory's decision to cut off estimates at 100 miles from the coast is not explained, raising the question of whether CARB should estimate the emissions out to the edge of U.S. territorial waters or assign 50% of total voyage emission from the last port called.[114]

- **Revise the 2016 CA Sustainable Freight Action Plan:** The 2016 plan talks about incentives for liquefied natural gas vessels.[115] The plan is now seriously out of date concerning GHG pollution from LNG vessels and should reflect the growing body of evidence that LNG is not a low-carbon alternative fuel.[116]

Policy Recommendations for U.S. Government Action

- The U.S. EPA could use its existing authority under Section 213(a)(4) of the Clean Air Act authority to establish a GHG emission standard for engines of ships calling on U.S. ports. In combination with its port control authority under international law this could establish an emission standard for passenger and cargo ships calling at U.S. ports, similar to the framework under the FuelEU Maritime regulation; or the fuel standard currently under consideration at the International Maritime Organization. The U.S. EPA could issue a finding of "harm" from OGV emissions (e.g. make an endangerment finding) and proceed from that to impose GHG emission controls and tighter NOx and particulate control requirements for marine vessels under the federal Clean Air Act. Access to U.S. ports and travel in U.S. territorial waters could be conditioned on compliance with those standards.[117]

The U.S. EPA could use its existing authority under Section 213(a)(4) of the Clean Air Act authority to establish a GHG emission standard for engines of ships calling on U.S. ports.

---

[113] We recognize that it is difficult to develop an accurate inventory of GHG emissions from shipping. Our review of the existing reports revealed a lack of consensus and coordination regarding approaches, data sets, and reference points (boundaries) for these emission calculations. The six studies relied on primary data sources from (i) AIS data coupled with vessel operating information and (ii) fuel sales data. However, different approaches (methodology, models, emission factors, etc.) resulted in a variety of total emission calculations. The lack of standardization makes comparability among the reports difficult. While there are some entities that are required to report their GHG emissions under federal or state rules (such as the EPA GHG Reporting Rule or pursuant to the California Air Resources Board regulations), the majority of emissions associated with marine shipping is not required to be reported under any standardized structure, so differences in approaches to voluntary reporting is also an issue. The reports that are focused on U.S. emissions also did not have consistency regarding the emission boundary used. But it is important to improve efforts, as it affects various levels of planning and regulation. *Report Of The Greenhouse Gas Inventory Project Blue Sky Maritime Coalition Measurements and Operational Efficiency* May 2023.https://www.bluesky-maritime.org/_files/ugd/8ed502_f11b1a537eae455b9ef896bd8921fad1.pdf

[114] https://ww2.arb.ca.gov/sites/default/files/2022-03/CARB_2021_OGV_Documentation.pdf

[115] https://ww2.arb.ca.gov/sites/default/files/2019-10/CSFAP_FINAL_07272016.pdf

[116] https://theicct.org/wp-content/uploads/2023/11/ID-64-%E2%80%93-FUMES-ships-Report-A4-60037-FV.pdf

[117] EPA rejected a petition to issue a finding of harm for NOx, particulate matter and GHG emissions from marine engines, a decision that was upheld by a U.S District Court. *Center for Biological Diversity v. USEPA, 794 F. Supp. 2nd 151 (D.D.C. 2011)*. EPA, however, appears to have discretion, under §213(a)(4) of the Clean Air Act to issue the harm finding, it just can't be compelled to do so by federal courts. 42 USCA §7547(a)(4). See, Wooley & Morss, *Clean Air Act Handbook,* 32nd Edition, §5:49, 2023 page 365, available on WestlawNext.

- Congress could amend the US Renewable Fuel Standard (RFS) to include maritime fuels.[118] The Renewable Fuels Standard is a market-based system to promote the production and use of renewable fuels in transportation. The Standard was enacted as an amendment to the Clean Air Act. It defines "transportation fuel" as fuel "for use in motor vehicles, motor vehicle engines, nonroad vehicles, and nonroad engines (except for ocean-going vessels)".[119] This appears to disqualify green methanol and ammonia fuels for eligibility to earn Renewable Identification Numbers or "RIN"s (credits used for compliance).[120] Moreover, the RFS is structured around biofuel. Some potential zero-carbon marine fuels can be made without biomass, and hence may not be eligible.

Congress could change the scope of the standard by eliminating the exclusion of ocean-going vessels and including so-called e-fuels.

Congress could change the scope of the standard by eliminating the exclusion of ocean-going vessels and including so-called e-fuels (e.g. those made from electrolytic hydrogen combined with captured carbon).[121] The objective would be to stimulate domestic production of green methanol (both e-methanol and biomethanol), green ammonia, biocrude, and other low- or zero-carbon maritime fuel options. This would tend to accelerate the production of these fuels, gradually reduce the cost of and increase the availability of these fuel options. Currently, users of zero-carbon marine drop-in fuels are at a disadvantage, as federal policy drives producers toward fuels that are eligible for revenue under the RFS. Congress could change this dynamic and thereby expand the potential for domestic renewable marine fuel production. This change could be introduced into the broader conversation about other needs for changes to the RFS legislation that is under consideration in Congress.[122] This discussion arises from the prospect of the long-term decline in renewable fuel use in road transport, due to vehicle electrification.

- Other actions Congress could consider include:
  - *Direct the U.S. Environmental Protection Agency to promulgate regulations to reduce greenhouse gas (GHG) emissions from marine*

---

[118] Energy Policy Act of 2005, Pub. L. No. 109-56,119 Stat. 594; amended by the Energy Independence and Security Act of 2007. 42 U.S.C.A. §7545(o).

[119] 42 USC §7545(o)(1)(L)

[120] https://www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard

[121] See, *Miller-Meeks, Garamendi Introduce the Renewable Fuel for Ocean-Going Vessels Act,* December 7, 2023, https://miller-meeks.house.gov/media/press-releases/miller-meeks-garamendi-introduce-renewable-fuel-ocean-going-vessels-act. The proposed legislation (H.R. 6681) would add maritime ship fuels to the federal renewable fuel standard and allow for RINs to be generated for renewable marine fuel. The bill is an amendment to the federal Clean Air Act addressing biodiesel and renewable diesel. https://www.congress.gov/bill/118th-congress/house-bill/6681 It is unclear whether this bill would apply to biomass derived methanol or ammonia ship fuels, which are expected to dominate markets for low or zero carbon fuels for ocean going vessels.

[122] See, Congressional Research Service, *A Low Carbon Fuel Standard: In Brief,* July 7, 2021, https://crsreports.congress.gov/product/pdf/R/R46835

vessels that call on ports in the United States. See Clean Shipping Act, S. 1917 and HR 4024;[123]

- *Impose a pollution fee of $150 per ton of carbon emissions from fuel used by vessels calling at U.S. ports.* Additional fees could also apply to emissions of nitrogen oxide, sulfur dioxide, and particulate matter. Revenues could be earmarked to support programs to reduce emissions from marine sources. See, International Maritime Pollution Accountability Act of 2023, S. 1920.
- *Modify existing U.S. port access fees*[124] *to reflect the carbon intensity of the transport mode*. Some portion of fee revenue could be used in a variety of ways to support innovative ship design/construction and alternative fuel port infrastructure development.
- *Amend the section 45Z tax credit to include low-carbon vessel fuels and extend eligibility beyond 2027.*[125] This provision of the Internal Revenue Code provides a tax credit for the domestic production of clean transportation fuels.[126]
- *Provide funding for zero-emission vessel construction.* Congress could establish a zero-emission vessel innovation fund to specifically support the research, development, demonstration, and deployment of zero-emission vessels (new vessels or retrofit[127] of existing vessels). The funding should prioritize technologies with environmental co-benefits such as underwater noise reduction (i.e., vessel quieting).

- The U.S. Coast Guard, likely in coordination with other federal agencies, will likely need to develop rules to implement IMO rules adopted to implement its 2023 GHG targets. Work should begin on this in early 2024 to ensure adoption at the earliest opportunity.[128] This could proceed in tandem with the development of a U.S. fuel standard, as there is some risk that IMO implementation measures may be delayed. Action by U.S. agencies would help guarantee that the IMO will carry through with its planned implementation measures.

- The Inflation Reduction Act (IRA) and Bipartisan Infrastructure Act contain powerful incentives (tax credits, loans, grants) and innovation structures (e.g. Hydrogen Hubs) to develop hydrogen-based fuel markets. But funding for port

---

[123] This bill would amend the federal Clean Air Act to require the EPA, no later than January 2026, to set standards for carbon intensity of fuel used in vessels. https://www.congress.gov/bill/118th-congress/house-bill/4024/text?s=1&r=4

[124] See, https://help.cbp.gov/s/article/Article-810?language=en_US

[125] See, S. 3002, a bill to amend the Internal Revenue Code of 1986 to modify the clean fuel production credit to provide a special rate for sustainable vessel fuel. https://www.congress.gov/118/bills/s3002/BILLS-118s3002is.pdf

[126] https://www.congress.gov/bill/118th-congress/senate-bill/3002/text?s=1&r=30

[127] See, https://www.lr.org/en/knowledge/horizons/march-2024/weighing-up-energy-saving-technology-options/

[128] For a summary of the Coast Guard proposed actions to implement IMO rules see, https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202310&RIN=1625-AC78
This notice appears to predate the July 2023 action of the IMO.

and vessel decarbonization is limited.[129] The Executive branch could request additional funding devoted specifically to domestic production of zero-carbon fuels and domestic shipbuilding to serve Jones Act trade corridors.[130] Funding could support retrofitted and new-build vessels designed for low- or zero-carbon emissions and reduced underwater noise.

- The IRA implementation could be strengthened in several other aspects:
  - The U.S. government could clarify that clean fuel tax credits are available for the production of vessel fuels.
  - Eligibility for tax credits for CO2 sequestration could be extended to operations to capture CO2 for use in making green methanol and other similar marine fuels.
  - Eligibility for tax credits for zero-carbon fuel production could be extended to fuels that are exported or used outside of U.S. waters for marine transport serving U.S. ports.

- The U.S. could establish a monitoring, reporting, and verification mechanism to collect fuel consumption and emissions data from all large ships that use U.S. ports. This would be used to implement other policy initiatives including: a) a GHG fuel standard for ships calling on U.S. ports; b) an extension of the Renewable Fuel Standard to fuels used in large ships; and/or, c) port entry fees or taxes differentiated by carbon Intensity of cargo transport. The U.S. system should be modeled on the European Union's Monitoring, Reporting, and Verification (MRV) system for ships.

- The U.S. could include shipping emissions within its Nationally Determined Contributions (NDCs) that it submits to the UNFCCC, and agree on a 50% per-voyage scope for international shipping emissions as the accounting method.[131]

- The U.S. EPA could require shore power for ocean-going vessels as part of its nonroad regulations, to achieve reductions in GHG and conventional air pollutants.[132] The infrastructure (increased capacity on the local grid) to support

---

[129] The Inflation Reduction Act includes a $3 billion rebate and grant program, managed by EPA to fund zero-emission port equipment and technical assistance for electrification, emission reduction planning and port climate action plan development. The U.S. Department of Transportation has used $703 million from the Maritime Administration's Port Infrastructure Development Program (PIDP) to fund 41 projects in 22 states to improve port facilities. The funding is authorized under the Bipartisan Infrastructure Law and additional Congressional appropriations. Much of the funding is being used to enhance conventional trade infrastructure or port facility electrification, with only limited amounts for alternative vessel fuel production and bunkering facilities.

[130] UMAS, *The Maritime Fleet of the USA – the current status and potential for the future.* January 2022 – Rev 2.0 https://www.u-mas.co.uk/wp-content/uploads/2022/04/oc_jaf_final_report_20220119.pdf

[131] See, Transport and Environment, *Less is more: Regional shipping policy and global decarbonisation Regulating shipping in Europe, the US and China could green 84% of the fleet*, https://www.transportenvironment.org/wp-content/uploads/2022/11/COP27_world_country_MRV-3.pdf

[132] In some cases, increased demand on the local electric grid can offset emissions avoided from at berth ship emissions. See, EPA's shore power calculator: https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports if interested

shore power can also support the electrification of cranes and other cargo-handling equipment. Port-side power connections would also be used by ships equipped with batteries used in hybrid propulsion systems. California ports have long been required to supply shore power for container ships, refrigerated cargo ships, and cruise ships. The state recently adopted rules to require shore power for tankers and roll-on-roll-off (RoRo) vessels.[133]

- Federal agencies and Congress could increase funding for the Marine Highway Program[134] to decarbonize ocean-going ships moving between U.S. Ports. Currently funding for this program is very small; adequate funding could help Jones Act Fleets experiment with zero-carbon propulsion and fuels.

- Similarly, Federal agencies and Congress could increase funding for low- and zero-carbon port infrastructure via the Maritime Environmental Technical Assistance (META), and the Maritime Administration's Port Infrastructure Development (PIDP).

- Federal agencies could actively support the creation of zero-carbon trade corridors (i.e., green shipping corridors) within the U.S. and between U.S. ports and major European and Asian ports.[135] Some U.S. states and ports have signed agreements to develop such trade corridors, but it is difficult to implement these without active support from national governments.

- The U.S. could phase out and ban scrubber systems in U.S. ports and waters. Some shipping companies install "scrubber discharge technologies" that dump oily-filled wastewater into the ocean before docking at ports. Scrubber systems should be banned as a means of compliance with clean fuel standards in U.S. waters or at U.S. ports. Worldwide, there is growing recognition of the impacts of sulfur scrubbers on water pollution and the marine environment.

The U.S. could phase out and ban scrubber systems in U.S. ports and waters

[133] The European Union has adopted shore-power requirements for all container and passenger ships beginning in 2023. This was contained in its FuelEU regulations adopted as a key part of the EU's Fit for 55 package. https://www.consilium.europa.eu/en/press/press-releases/2023/03/23/fueleu-maritime-initiative-provisional-agreement-to-decarbonise-the-maritime-sector/; https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/; https://www.dnv.com/maritime/insights/topics/fuel-eu-maritime/index.html

[134] https://www.maritime.dot.gov/grants/marine-highways/marine-highway.

[135] See, ICCT, *Jones Act Shipping Case Studies: Feasibility Of U.S. Domestic Green Corridors With Hydrogen And Wind Assist,* December 14, 2023. The paper examines four aging Jones Act vessels and their potential to use renewable liquid hydrogen and two wind-assisted technologies, across four key Jones Act corridors—the Pacific Northwest, West Coast, Pacific, and the Great Lakes. It finds that the four vessels could complete 99% of their routes using liquid hydrogen. https://theicct.org/publication/jones-act-shipping-case-studies-dec23/

Recommendations for Port Authorities and Local Government

- **Fees and funding.** The Port of LA recently provided $60 million for electrification of trucking and cargo handling equipment, raised from fees on fossil fuel-powered trucks entering the port. A similar system of fees could be imposed (or added to existing port access fees) to reflect the impact of OGV GHG emissions and support grants that help increase low- and zero-carbon ship calls.[136] This kind of incentive mechanism is mentioned in CARB's 2018 Technology Assessment and California's 2016 Sustainable Freight Action Plan.

- **Just In Time Port/Ship operations.** Research suggests that ports and terminal operators can adjust operations to reduce a wide range of emissions through improvements in scheduling, coordination, communications, and software. Often referred to as "just in time," these logistics innovations have the potential for large economic and environmental benefits.[137] The Port of Rotterdam has studied a system to track vessel arrival time, ensure ships are not held offshore for extended time and have access to clean energy supply in port to reduce auxiliary emissions.[138] The Ports of Los Angeles and Long Beach have implemented such a since 2021.[139] The Port of Singapore began to implement a Just In Time system in 2023 and 2024.[140]

Recommendations for the Private Sector, Industry Associations, and NGOs

- **Support effective and enforceable IMO implementation rules.** Industry support for the current "implementation" round of IMO negotiations will be critical, including a proposed global fuel standard which is aligned with IMO Revised GHG Strategy and 1.5°C pathway.

- **Clean Fuel Planning Collaborative:** Refineries, terminal operators, and shipping lines could encourage and participate in collaboratives in the San Francisco and San Pedro Bay areas to coordinate the development of feedstocks, production,

---

136 This concept has been discussed by CARB staff as a means of encouraging ships to adopt engine systems which produce less conventional air pollution emissions. The idea was to reduce port-call fees for ships with Tier II (or better) engines and high scores on the Environment Ship Index. See, https://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/ogv-presentations-combined-04-01-21.pdf?sfvrsn=20

137 See, ; Global Maritime Forum, *National and regional policy for green shipping corridors*, https://www.globalmaritimeforum.org/publications/national-and-regional-policy-for-green-shipping-corridors; and Marine Traffic, *Just In Time Arrival Emissions reduction potential in global container shipping,* https://greenvoyage2050.imo.org/wp-content/uploads/2022/06/JIT-Container-Study.pdf; https://greenvoyage2050.imo.org/just-in-time-arrivals/#chapter5

138 See, Port of Rotterdam, *Up to 14% less containership CO2 emissions through Just In Time arrivals,* https://www.portofrotterdam.com/en/news-and-press-releases/up-to-14-less-containership-co2-emissions-through-just-in-time-arrivals

139 https://mxsocal.org/assets/pdf/announcements/container-vessel-queuing-process-for-la-lb-oak-v-2.pdf

140 https://www.marinelink.com/news/singapore-highlights-maritime-512029?utm_source=MR-ENews-Weekdays-2024-03-06&utm_medium=email&utm_campaign=MR-ENews

and bunkering of zero-carbon fuels. This could encompass just liquid OGV fuels, or be expanded to aviation fuels, and energy inputs needed for various industrial processes. The City of Yokohama convened an effort like this beginning in 2021. The result was a plan for zero-carbon fuel or feedstock production, import and export infrastructure, and a pipeline system to connect ports, refineries, steel mills, petrochemical plants, wastewater treatment plants, and other facilities that can either produce or utilize green hydrogen, ammonia, captured carbon and methane in their operations or production.

- **Cargo Owners Commitment to Clean Shipping:** Cargo owners often referred to as "shippers," can respond to consumer preference for low-carbon shipping by joining voluntary markets for clean cargo transport. One such system, being organized by Aspen Institute is CoZEV, which is a group of retail brands that plan to gradually switch all their ocean freight to vessels powered by zero-carbon fuels by 2040.[141] CoZEV is a platform for corporate customers of the shipping industry to accelerate the transition to zero-emission shipping. Amazon, Brooks Running, Frog Bikes, IKEA, Inditex, Michelin, Patagonia, Tchibo, and Unilever were the first signatories to a 2040 Ambition Statement.[142]

- **Revenue sharing:** The Member States of the IMO have agreed to a "basket of midterm measures." Private sector support will help secure a GHG pricing mechanism that supports a global just transition. Disbursement of revenue raised through a GHG pricing mechanism can stimulate the early use of zero-emission fuels and contribute to transition funds for Small Island Developing States (SIDs) and Least Developed Countries (LDCs).[143] For more information, see *The implications of the IMO Revised GHG Strategy for shipping*.[144]

[141] https://www.cozev.org/img/110922_Roadmap%20to%202040.pdf

[142] Current member companies are listed at: https://www.cozev.org/aboutcozev

[143] https://cms.globalmaritimeforum.org/wp-content/uploads/2023/11/Insight-brief_The-implications-of-the-IMO-Revised-GHG-Strategy-for-shipping.pdf

[144] https://cms.globalmaritimeforum.org/wp-content/uploads/2023/11/Insight-brief_The-implications-of-the-IMO-Revised-GHG-Strategy-for-shipping.pdf

Section 4: **Conclusion**

We are optimistic that the seaborne cargo industry can, in the near term, achieve a sharp reduction in GHG emissions and air pollution from ships, while retaining industry prosperity and protecting national, subnational, and local interests. This will require high levels of cooperation among governments and private sector leaders. Recent experience suggests that many powerful interests have begun to "pull together" to address the need to reduce emissions from ocean-going vessels. It is clear that we have, or soon will have, the technology to achieve this. Moreover, there are multiple policy pathways to deeply decarbonize ship operations. All of this together lays the foundation for a fully decarbonized shipping industry by 2040. As the world confronts the challenges posed by climate change, success in curbing OGV emissions will inspire work to address other, so-called, hard-to-decarbonize sectors.

There are multiple policy pathways to deeply decarbonize ship operations. Moreover, is clear that we have, or soon will have, the technology to achieve this. All of this together lays the foundation for a fully decarbonized shipping industry by 2040.

GOLDMAN SCHOOL
OF
PUBLIC POLICY
UNIVERSITY OF CALIFORNIA BERKELEY

https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/ocean-going-vessel-decarbonization

PACIFIC ENVIRONMENT

www.pacificenvironment.org